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A Summary of Current Program, 4/1/67

and Preliminary Report of Progress

for 4/1/66 to 3/31/67

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AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

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CURRENT SERIAL RECORDS

This progress report of USDA and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between April 1, 1966, and March 31, 1967. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland

UNITED STATES DEPARTMENT OF AGRICULTURE

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TABLE OF CONTENTS

	<u>Page</u>
Introduction	i
Area No. 1: Soil-Machine Relationships.....	1
Area No. 2: Planting and Fertilizing Operations and Equipment.....	10
Area No. 3: Crop Pest Control Techniques and Equipment	18
Area No. 4: Crop Harvesting and Handling Operations and Equipment.....	30
Area No. 5: Crop Preparation and Farm Processing (Except cotton).....	55
Area No. 6: Cotton ginning.....	63
Area No. 7: Structures for Crop and Machinery Storage and Plant Growth.....	78
Area No. 8: Rural Dwellings.....	83
Area No. 9: Livestock Engineering (Except Electrical).....	89
Area No.10: Construction Standards, Water Supply, Wastes Disposal and Farmstead Planning.....	106
Area No.11: Electromagnetic and Ultrasonic Energy for Insect Control and Other Farm Uses.....	116
Area No.12: Electric Equipment for Farm Labor Reduction.....	132
Area No.13: Electric and Solar Equipment for Environmental Control.....	137
Area No.14: Farm Electric Service and Instrumentation.....	144
Line Project Check List.....	147

INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements, for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of the approximately more than 3-1/4 million farms. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm labor have been reduced by 55 percent, from 18.8 billion to 7.5 billion, the number of tractors has doubled, from about 2.4 million to 4.6 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 98. Each farm worker has available between 35 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over \$30,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is \$100,000 or more.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations in this field compared to that of public research in other fields of agriculture. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

In commenting on Balance among Phases of the U.S.D.A. Research Program in its report of April, 1965, the National Agricultural Research Advisory Committee stated, "Problems in agricultural research are constantly changing in relative importance necessitating a periodic review to maintain a proper balance. -----
It believes the current level of engineering research both on the part of the USDA and the State Experiment Stations is too low."

The 1966 report of the National Agricultural Research Advisory Committee in commenting on Protection of Man, Plants and Animals, recommends intensifying all phases of research in waste disposal including the utilization of waste from farms.-----.

In commenting on Efficient Production and Quality Improvement, the committee reaffirms its previous recommendation-----and that increased emphasis be placed on agricultural engineering studies with the objective of achieving an agricultural industry that is more productive, efficient and profitable--.

The Committee recommends that a completely new look be taken at forage harvesting, transportation, storage and feeding to achieve significantly improved efficiencies in handling and digestibility. It also recommends enlarging the research effort on controlled environmental studies of live-stock and poultry. It also points out the serious lag in mechanization of milking compared to other areas.

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such cooperation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 31 of its 172 professional workers located at the Beltsville Agricultural Research Center; 48 at 18 federal field stations, and 93 at 32 State Experiment Stations.

Of the 141 Division professional workers now at field locations, 39 are in 9 specialized federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National significance. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research, involving about 44 engineers, conducted at 24 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

As a step toward implementation of the recommendations for a National Program of Research for Agriculture made jointly by the Association of State Universities and Land Grant Colleges and the USDA, examples of achievements resulting from State and State-USDA cooperative research are shown.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Predict Forces on Tillage Tools by Models. Research engineers have found that it is possible to predict the draft forces on tillage tools, similar to moldboard plows, from tests made on small models of such equipment. The prediction can be made based upon a dimensional analysis of the tool-soil system, and certain measurements made of the soil properties. Previous predictions of tillage tool performance from models was limited to a single soil. Latest work shows that prediction from one soil type to another is possible if the correct soil measurements are made. The soil measurement which appears to have the greatest value in predicting performance is the internal cohesion.

(2) Deep Tillage in Cotton. Cotton is frequently grown in the southeast on soils which are rather heavy and susceptible to further compaction by traffic from tractors and other farm equipment. Experiments have been conducted by ARS engineers, tilling immediately under the planting row with subsoilers to a depth of 18 inches. This type of tillage, coupled with

other cultural practices which eliminated recompaction of the tilled area, has resulted in increased cotton yield up to 50% in certain soil types. The effect of this type of tillage method appears to have been of value in experiments both in the southeastern and western cotton growing areas.

(3) Migratory Agricultural Worker Housing. Cooperative research with the Public Health Service, DHEW, has developed plans and planning guides suitable for use by architects, engineers, builders, lending agencies, extension workers, government officials, growers and others concerned with housing migratory and seasonal agricultural workers. These materials cover a range of sizes and types of economical, practical housing units for families and single males. Eleven of these plans have been incorporated into a publication, "Family Housing for Migrant Agricultural Workers," to help fill the urgent need for family type housing created by recent legislation restricting importation of foreign labor for critical harvesting tasks.

(4) Combined Use of Light and Sex Attractants Increases Moth Catches. Blacklight (near ultraviolet) trap catches of tobacco hornworm moths increased significantly when virgin females were placed in the vicinity of the traps in North Carolina experiments. In similar tests with the cabbage looper in California, placement of live virgin female moths in the vicinity of light traps was found to increase collections of male moths from 4 to 95 per trap per night. Similar increases in catch of males were observed when a synthetic sex pheromone replaced the caged virgin females. Further testing of this response by the hornworm moths is being made on the island of St. Croix, V.I., where 240 blacklight traps are in experimental operation to control the insect. Additional work of the same type with the cabbage looper was initiated near Red Rock, Arizona, in late 1966 with the installation of 400 blacklight traps and synthetic sex pheromone added to determine possible control of this pest in 2,000 acres of lettuce.

(5) Electricity Warms Soils for Sport Turf. Results of five seasons of research in cooperation with the Purdue University and Minnesota Agricultural Experiment Stations show that cold-season soil warming can be included in modern turf management. The density of heat required was found to depend on the weather conditions at a particular location. Both polyvinyl-chloride insulated, nylon-jacketed cables and mineral-insulated, copper-clad cables performed satisfactorily. Based on this research program, specifications were prepared and electric heating cables were installed in the turf of the new Civic Center Busch Memorial Stadium at St. Louis and in the Air Force Academy Stadium at Colorado Springs. These are the first such installations in the United States and were completed late in 1966.

(6) Mechanized Burley Tobacco Handling. A mechanized method of handling harvested Burley tobacco on portable curing frames has been developed in cooperation with the Kentucky Agricultural Experiment Station. Using a front-mounted tractor loader, steel or wood frames, filled in the field, are stacked in a clear-span curing structure. The cured tobacco may be removed from the barn while out-of-case, and placed into a steam casing chamber. This allows stripping of the cured leaf and preparation for the

early market, regardless of climate conditions. Mechanizing the combined operations of transport between field and barn, housing, and casing have resulted in a 35 percent reduction in man-hour requirements for handling from the time after harvest through casing.

The following examples of research accomplishments were supplied by CSRS:

(1) Machine Relationships. Traction efficiency of dual-tired tractors can be improved. Laboratory research at the Indiana Agricultural Experiment Station indicated that dual tires should be placed as close together as possible without permitting the inside of the tires to touch each other. The reduced tire spacing resulted in reduced tire sinkage in soft soil, improved power efficiency and improved traction force of about 12%.

(2) Planting and Fertilizing Operations and Equipment. New methods have been developed to permit planting of small seeds. At the New York Agricultural Experiment Station at Cornell, engineers have developed a new planter that uses a tape on which seeds are glued at the desired spacing. At equivalent speeds of four miles per hour, seeds were deposited at spacings of three inches plus or minus two-tenths of an inch. At California, engineers developed a vacuum seed pickup planter that will select and plant single small seeds at regular intervals and reduce the amount of seed required by 90%. The planter will select and pick up single seeds of irregular shape, such as lettuce seeds, and space them in intervals to permit easy thinning by machinery. The new planter reduced labor required to hand thin lettuce fields by 45%.

(3) Crop Pest Control Techniques and Equipment. The coverage of plant surfaces by pesticide sprays can be improved by placing an electric charge on the spray particles. Scientists at the North Carolina State Agricultural Experiment Station have shown an average increase of 3.8 times in the coverage of the bottom of the leaf because of charging of spray particles.

(4) Crop Harvesting and Handling Operations Equipment. Increased shortage of labor has made it necessary to mechanize harvesting of apples. Research at the Pennsylvania State Agricultural Experiment Station has developed two harvesting machines. One is a picking aid to improve efficiency of hand pickers. The need for ladders is eliminated by keeping pickers on a platform placing them in a better picking position in the trees. The second machine eliminates the need for hand picking. An apple catching frame is placed high in the tree and apples are shaken from the tree onto the frame and conveyed to a bulk box handling scheme with a minimum of damage to the apples.

(5) Crop Preparation and Farm Processing. Peanuts must undergo a curing process to develop and maintain proper quality for consumer acceptance. Research at the Oklahoma Agricultural Experiment Station indicated that curing using dielectric or internal heating with reduced air flows can result in better and faster curing. Research is being continued to further develop this curing method.

(6) Rural Dwellings. Soil or earth has been used for thousands of years for construction of fences, walls, houses and animal shelters and is still used in various parts of the world today. Research at California has shown that adobe or soil-cement bricks can be strengthened by as much as 50% to 100% over the normal strength by the application of high pressure in the forming process. Such pressurized bricks often display greatly increased stability and resistance to water. Pressure machines are being used worldwide with excellent success in areas of low labor cost.

(7) Construction Standards, Water Supply, Wastes Disposal and Farmstead Planning. The increased numbers of cattle in commercial feedlots has resulted in much greater concentration of animal wastes. Such wastes may be washed into streams with runoff from rainfall causing pollution of streams. Research at Kansas State University has begun to measure both quality and quantity of the runoff from streams. Cattle feedlot runoff was shown to be a high strength organic waste, containing large concentrations of nitrogen. Based on organic matter content, one gallon of feedlot runoff is equivalent to two to seven gallons of average municipal sewage. Research is continuing to develop methodology that will minimize pollution from feedlots.

AREA NO. 1: - SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle chassis, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved response of crops and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; and State College, Mississippi. USDA personnel working on this project are stationed at Auburn, Alabama; Ames, Iowa; Stoneville, Mississippi; and Shafter, California. Much of the work at the National Tillage Machinery Laboratory at Auburn is cooperative with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests and field observations.

The Federal scientific effort devoted to research in this area totals 11.3 scientific man-years. Of this number 1.8 are devoted to traction and transport devices and soil reaction; 3.5 to the effect of tillage practices on plant growth; 1.2 to the measurement of soil physical properties; 3.3 to equipment mechanics; and 1.5 to systems of equipment for conservation farming.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Investigations are in progress on ways to develop and apply more efficient methods of soil manipulation that will produce improved soil physical conditions for seed emergence and optimum plant production; development and evaluation of systems of tillage which offer possibilities in reducing time, labor, or equipment to produce a crop; determination of fundamental and predictable relationships between external energy applications and soil breakdown and consolidation; exploration of techniques necessary for improvement of deteriorated soil structure and soil tilth; probing into possible ways that traction and flotation of farm machines might be improved to overcome the problems caused by compaction; and measurements of power requirements, stresses and wear on tools and equipment as an aid to improved farming efficiency.

Many of these research investigations are cooperative with the Department. A total of 18.4 scientific man-years per year of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Traction and Transport Devices and Soil Reaction.

1. The effects of diameter on performance of power tractor wheels was found at the National Tillage Machinery Laboratory, Auburn, Alabama. Results of tests, now concluded, on smooth and lugged pneumatic tires (12.4/11 x 24", 36", and 42") and steel wheels (40", 50" and 60" O.D.) indicate that a larger diameter wheel will give increased pull at same load (and inflation pressure for tires). Load carried on wheel is more effective than diameter, therefore increased load carrying ability of larger diameter tires makes them doubly effective. Tests were conducted on 5 different soils plus concrete, using loads between 2000-2800 lbs. Tests were conducted to evaluate 3 different lug configurations being considered for production by United Cooperatives; no significant differences could be found in performance.

B. Effect of Tillage Practices on Plant Growth.

1. In crop residue disposal studies at Stoneville, Miss., an experimental stalk and root ejector was designed and evaluated in preliminary field trials. The device, which is an attachment to a modified stalk shredder, consists of two 12" disks, arranged to pull the roots out of the soil after the top is shredded. In the first test it was difficult to keep the puller centered over the row, but better guidance systems may solve this problem in the future.

2. In tillage studies, the transfer of soil layers study continued to show yield response on Tunica silty clay at Stoneville for the fourth year. Tillage treatments were repeated on the same plots except the deep mixing treatment which was treated the first year only. Double bedding, subsoiling, and deep mixing produced the highest yields again last year.

3. Field studies were conducted for the second year comparing a strip-tillage system of seedbed preparation with a conventional method of preparation at Auburn, Ala. Method of preparation did not affect emergence, growth, or yields of cotton. These results are in agreement with those of 1965.

Several combinations of precision tillage, optimum tillage, minimum tillage, etc. were installed at Shafter, Calif., in an effort to clarify the interaction of tillage method and Verticillium wilt reported last year. Wilt damage was greater in precision-tilled plots than in the minimum tillage plots. The precision-tillage plots were not visibly different from the normal-tillage plots, nor were the normal-tilled plots visibly different

from the minimum. A strong correlation was found between wilt damage and plant growth prior to infestation. Yield differences were not significant. At the Westside Field Station, penetrometer measurements indicated that the effects of precision tillage lasted longer under sprinkler irrigation than under furrow irrigation.

An integrating penetrometer for obtaining average soil strength was developed at Shafter. It includes a force transducer, an operational amplifier and a DC signal generator as the main components. The force required to move the penetrometer cone through the soil is sensed by a probing ring equipped with electrical strain gages. The strain gage bridge excitation is supplied by a DC generator mechanically connected so that the output voltage is proportional to the rate of penetrometer probe insertion.

4. Attempts were made in cooperation with the Alabama Station, to evaluate the effect of a compacted layer (bulk density 1.8) and low soil pH (less than 5 in the 6 to 18 in. depth) on cotton yield in Norfolk sandy loam soil. Lime applications to the subsoil failed to correct pH uniformly. The compacted layer reduced taproot size and distorted its shape. Feeder roots were slow in penetrating compacted layer but proliferated in subsoil later in the season. No difference occurred in yield.

Tillage to an 18" depth with subsoilers and planting over the tilled soil volume in the same operation gave an increase in cotton yield in Chesterfield loamy sand of 35 percent, Augusta fine sandy loam of 53 percent, and Greenville sandy loam of 6 percent. A decrease was observed in Decatur clay loam of 21 percent and Hartselle fine sandy loam of 14 percent. No yield differences were found in Greenville silty clay, Magnolia sandy loam, or Norfolk sandy loam.

5. Root system development of cotton produced under ideal climatic and soil situations was observed at the National Tillage Machinery Laboratory. Daily measurements of root elongation, length of growth period, and life were recorded and correlated with top growth both during the expanding and established root system stages of development. A taproot can maintain a mean 1-3/4 -inch/day elongation rate over an extended period of time. In less than 7 weeks after planting, the cotton taproot is capable of extending to a depth of 6 feet. From other studies, it appears that roots can develop normally in soil moisture contents between permanent-wilting-percent-age + 1 percent field capacity as long as the physiological requirements of the plant are met. This conclusion was reached from studies utilizing corn and sugar cane grown in split-root containers to which a portion of the roots are supplied with adequate water for the plant's requirements.

C. Measurement of Soil Physical Properties.

1. Factors influencing the cone index of soil were studied at the National Tillage Machinery Laboratory. Measurements were made of penetration

resistance, shear, cohesion, friction, adhesion, bulk density, and moisture in Norfolk sandy loam and Decatur clay loam soils. A relation was found between cone index and bulk density for each soil. A relation was found between cone index and cohesion and friction. No relation was found between friction and adhesion.

Triaxial tests were conducted at the National Tillage Machinery Laboratory on loose unsaturated samples of four natural and two artificial oil soils at constant liquid content. Data obtained seemed to define a compaction surface in a three-dimensional yield diagram with coordinates mean normal stress, maximum shearing stress, and bulk weight volume. This compaction surface was bounded by a critical state curve at which maximum compactness for a stress state was achieved and yielding in shear was observed. An equation was determined which described this compaction surface. Data on an associated compaction surface representing yielding in shear was obtained but the shape of this surface and its equation could not be verified.

D. Equipment Mechanics.

1. In cooperation with Lilliston Implement Company, new designs of sub-soilers that cut at three depth increments were compared at the National Tillage Machinery Laboratory with those cutting once at the maximum depth. The former required considerably more draft than the latter. Soil forces on slicer tines developed by Lilliston Implement Company were measured. The vertical forces were too high. Suggestions were made for redesign. Tests on the new product are now being evaluated in several locations in the U.S. by Lilliston.

Literature was reviewed at the National Tillage Machinery Laboratory on rotary tillage in U.S., Japan, England, Germany, and Russia. A cooperative agreement was initiated with the International Rice Research Institute for a study of rotary tillers for rice culture. Equipment was designed for tests of tiller blades. This equipment is now being constructed. A technical review was prepared of research work on oscillating tillage tools.

Results at the National Tillage Machinery Laboratory from a cooperative project with International Harvester Company indicate that similitude techniques can aid in the evaluation of bulldozer blade design factors. Studies were made on the effect of the angle between the wings, vertical approach angle, width of cut, and speed on soil forces on sweeps. Similitude techniques were used and tests were made in a sand and sandy loam. Additional data were collected on triangular vertical chisels to better establish the relationship of the draft to depth/width ratio and to the included angle.

Values of wear resistance and friction-adhesion were made on 24 samples of steel with various compositions and heat treatments at the National Tillage Machinery Laboratory. The steel was made and furnished by U.S. Steel Corporation. There was very little variation in the magnitude of friction-

adhesion due to variations in samples. While wear resistance varied considerably, no one factor seemed to control wear resistance.

New equipment and instrumentation is being developed and constructed at the National Tillage Machinery Laboratory for measuring the performance of soil tool systems. Slip computer: A special purpose analog computer for calculation of slip in traction studies is currently being designed and developed. The computer will feature automatic closed-loop control of initial conditions. Hand penetrometer: The design and development of an X-Y recording, battery powered hand penetrometer is currently under way. Soil strength measurement unit: A car was designed and built for use in measuring the strength of soil in the National Tillage Machinery Laboratory bins. It includes a newly designed hydraulically operated penetrometer which provides continuous plotting of penetration resistance vs. sinkage and an annulus shear apparatus.

E. Systems of Equipment for Conservation Farming.

1. In research in cooperation with the Iowa Station, plowing, disking, harrowing, and two cultivations were successfully eliminated without significant reductions in corn yields with early spring applications of Atrazine and Simazine. Preplant tillage with a disk or strip tiller after spraying, improved stands and weed control, but did not increase yields.

When weeds were controlled with Atrazine, there was little or no effect on yields observed among 10 tillage systems on 30-inch corn when stands and fertility levels were equal. Inputs of fuel, labor, and time were measured along with yields, for various tillage systems used in corn production in order to make economic evaluation of the various systems. Preliminary results show a strip-rotary tillage system used in combination with planting is the most economical. A soil surface profile meter was developed to collect data automatically on IBM cards so that a quantitative description of soil roughness can be determined. Vibration of a simple tillage tool reduced the draft but not the total energy input. Soil clod size changed with amplitude and frequency of vibrations. An equation was developed to determine soil shear strength from penetrometer readings.

F. Foreign Research Under Public Law 480 Funds.

1. Work has continued on a three-year project by the University of Bologna, Italy, on development of methods and equipment for breaking up cohesive clay soils into small clod sizes for deep tillage. The revised completion date on this project is now October 1967, and we expect a final report after that time.

The cutting force of a wire through four kinds of soil was determined by means of laboratory tests on river silica sand, Ozzono clay, Cadriano soil and Le Budrie soil. During the tests the soil, previously mixed and brought

to desired moisture content and density, was cut with special apparatus using wire for the cutting edge. The forces necessary to pull the wire through the soil will be used as values for developing formulas for determining the tenacity or cohesiveness of any particular soil.

In another series of laboratory tests, the horizontal component of a model tillage tool was studied under four working conditions: with a stationary (non-vibrating) tool, with vertical oscillation, with transversal oscillation, and with both vertical and transversal oscillation. The reduction of draft due to vertical oscillation was negligible, due to transversal oscillation was up to 15 percent, and due to a combination of both types of oscillation was up to 25 percent. Frequency of vibration was 100 cycles per minute.

Field tests were continued with five types of moldboard plows at depths up to 52 cm. (20 in.). Three types of rotary implements were tested: Civello type TM 60, Nardi type misto, and Civello type PM 18; at depths up to 52 cm. (20 in.). A special subsoiler NR₃ was tested at depths up to 54 cm. (21 in.). Field experiments were conducted during June and July, but unusually heavy rains made the soil unworkable during the last half of August and beyond. (These were the same rains that contributed to the disastrous floods in the vicinity of Florence last winter.) More thorough interpretation is reserved until the end of the program; however, at this time a hypothesis seems possible that with the different implements there is a correlation between the soil shattering and the type of implement used.

2. Work was continued on a three-year research project by the Volcani Institute of Agricultural Research at Rehovot, Israel, on the influence of tillage operations on soil physical conditions related to crop growth.

A dryland farming experiment was initiated at Revadim, Israel. In a typical dryland farming region having an average rainfall of 400 mm. (15.7 in.) on a deep sandy loam soil. The first-year's included 3 primary tillage treatments (shallow plowing, deep plowing, and subsoiling), and 2 secondary tillage treatments (cultivation vs. spraying for weed control). Sorghum was planted and observations made during the growing season on germination, flowering, root distribution heading, and grain yield. Absolute yields were highest with deep-plowing treatments, but most efficient tillage system will depend on economic analysis of several season's data.

An irrigated farming experiment was begun in Gan Shmuel, Israel, in a relatively humid region with average rainfall of 600 mm. (23.6 in.) with deep, uniform and expansive clay or clay loam soil. Continuous cotton was used for indicator crop permitting study of residual and cumulative effects of tillage systems. The same primary tillage was used as at Revadim plus a minimal tillage treatment (discing, no plowing or subsoiling). In addition, 2 ridging treatments were added (precision tillage): permanent ridge-beds vs. shifting ridge beds. Practically no roots were found beyond 150 cm. (59 in.). In general root penetration was deeper in plowing and

ridging treatments than in discing and subsoiling. Discing plots showed no roots beyond 120 cm. (47 in.). Statistical analysis of crop yields are not yet available.

3. Work was continued on a three year project by the Volcani Institute for Agricultural Research, Beit Dagan, Israel, to find the effect of knife angle and velocity on the cutting of roots and rhizomes in the soil. In the first stage of study, investigations were conducted with single roots and mainly in the laboratory, in order to study the mechanical properties of the roots, and their behavior when pressed into the soil by the knife. Rhizomatous roots of Bermuda grass (*Cynodon dactylon*) were selected for the first experiments, as this plant is a widespread, problematic perennial weed. Synthetic fibers were tested to replace rhizomes in the laboratory experiments. Behavior of rhizomes under knife action was studied in the laboratory in small containers. Rhizomes were clamped at both ends in most of the experiments, simulating the condition when cultivator knives are acting on roots in the soil prior to cutting. Longitudinal forces developed in the rhizomes were found to be in the range of the tearing force, therefore, some of the rhizomes were torn rather than cut. Knives of three degrees of sharpness were used, but there was no indication that this factor influenced the number of rhizomes that were cut or torn.

4. A five-year project was negotiated in September 1966 with the Institute of Agricultural Mechanization and Electrification, Warsaw, Poland. This project will investigate the energy requirements, under different soil conditions, of tillage tools with non-rotating or non-vibrating elements compared to those having "active" elements or combinations of active and non-moving parts, with the objective of developing tillage machines with lower energy requirements.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA NO. 2: PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The row spacing used on many crops is still that which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the past have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

The greatest need in cotton production is cost reduction. Seedbed preparation remains one of the costliest operations in production in many areas; and planting is plagued by the uncertainty of getting a stand and the urgency of timeliness and precision. Research has begun to develop optimum tillage systems in some areas but they need further development and extension into other soils and climates. Although some progress is being made, more basic knowledge of the micro-environmental requirements of the cotton seed is needed; and this needs to be translated into planting equipment

to give better precision in the control of seedbed physical conditions. Better control of the seedbed shape, size, spacing and seed position will also have a direct bearing on the economy of using new and more potent pesticides.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of applied engineering research on planting methods and means of applying fertilizer on various crops. Cooperative studies are in progress in nine states (Florida, Georgia, Louisiana, Maryland, Michigan, Montana, New Mexico, Texas, and Washington). The professional staff members with their respective laboratory and engineering facilities are headquartered at three locations: in the East at ARC, Beltsville, Maryland; in the Southeast at Athens, Georgia; and in the Southwest at Bushland, Texas. Thirty-two field experiments were conducted cooperatively in 1966 with either State experiment stations, other ARS Divisions, or commercial research organizations.

In the spring of 1958, cooperative endeavor was requested of ARS to determine effective means of removal of hazardous contamination to agricultural lands that may result from nuclear explosions, by use of farm and industrial equipment. This work is cooperative with SWC and is conducted under contract and funds of the Atomic Energy Commission.

The Federal scientific effort devoted to research in this area totals 7.4 scientific man-years. Of this number 0.9 is devoted to fertilizer placement and distribution equipment; 0.1 to seed planting equipment; 0.1 to trans-planting and fertilizing equipment; 1.4 to equipment for establishment of forages; 2.5 to cotton seedbed preparation, planting, and fertilizing equipment; 0.6 to vegetable planting equipment; and 1.8 to decontamination of agricultural land.

PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Involved in these studies are design and testing of the several elements of machines together with investigations of the mechanics of seedling emergence. Basic research is also under way in an effort to determine the

environmental conditions that are necessary for maximum emergence and how these conditions may be controlled or altered with mechanical equipment. Companion to these overall studies are limited testing, improvement and development of equipment for aerial applications of seed and fertilizer.

A total of 11.2 scientific man-years per year of research effort is devoted to this work.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Fertilizer Placement and Distribution Equipment.

1. Cooperators at the Northern Great Plains Soil and Water Research Center, using special fertilizer application machinery furnished by AE, report that with wheat a positive yield response was consistent with increasing N application rates and was highest when combined with phosphorus. Yields were consistently lower from surface applications compared to 4 and 8 inch depths of fertilizer placement.

2. Research has been conducted under a grant to the North Carolina Station to control tobacco production and curing as related to health factors. Growth equipment is being developed to monitor growth continuously. Studies of effect of root temperature, gaseous composition in the root zone and soil moisture level were initiated. Field experiments were conducted in order to study modification in leaf properties due to harvest procedure. Samples are being evaluated by a cooperating tobacco company for major chemical and physical properties. Orders have been placed for two small environment test chambers for more precise laboratory curing studies.

B. Equipment for Establishment of Forages.

1. In studies of methods of establishing Coastal bermudagrass, ratings of plots the second year are listed by treatments in order of effect (best treatment first): (1) herbicides after sprigging (with good moisture), (2) water with sprigs, and (3) precision placement of fertilizer. Water with sprigs was much more beneficial when no herbicides were used and a poor growing season (scant moisture) was encountered. Four specially designed machines were provided, the special grassland drill used with the rye grass-oats experiment was redesigned, and a new pasture machine was started for the fescue and rye interseeding in Midland bermudagrass.

In Maryland, crownvetch seeded into bluegrass pasture without tearing up existing plants, produced yield increases equal to complete renovation of pasture to orchardgrass-ladino clover. Birdsfoot trefoil seeded into the same pasture increased yields but significantly less than crownvetch or complete renovation. Earlier research cooperative with the Maryland station demonstrated that the production of Midland pastures can be nearly doubled by seeding cool-season annuals into the existing sward. Preliminary new data indicate that the seeding of cool-season perennials is no more productive than the annuals and much more difficult to manage.

Cooperators at the Western Washington experiment station, using placement machines designed and constructed by AE, found that the mean yield of timothy from the 30-inch spaced band-fertilized rows exceeded that of the 7-inch broadcast fertilized rows by over 100 percent. Rates of N application varied from 0 to 120 pounds per acre. Similar results were obtained with orchard grass. Also compared were the effects of a complete fertilizer (80-80-80 lbs. per acre) applied at one of three different dates, approximately August 1, September 1, and March 15. Both 7-inch spaced rows with broadcast fertilizer and 30-inch rows with band fertilization were tested. Yields of timothy in 30-inch rows were higher for September fertilization than for either August or March. Mean yields of timothy and orchardgrass were greater by more than 100 and 60 percent, respectively, when seeded and fertilized in 30-inch rather than 7-inch rows. At Big Spring, Texas on Amarillo sandy clay loam the seedling survival of certain grasses was evaluated after three variations in soil tillage: deep plowing, normal field density, and compacted. Chiseling to a 30-inch depth with a vibrating chisel was applied to one half of the "normal field density" and "compacted" plots. Greatest seedling survival was from plantings in the normal field density plots, and very little effect was observed from the deep vibrating chiseling.

2. Research under contract with the New Mexico station has developed equipment which will operate with a plow and seeder to place plowed up brush on the seeded strip during one pass over the rangeland. Previous research by ARS has shown that a relatively sparse cover of brush is effective in cooling the ground and conserving moisture. This favors germination of seeds and plant emergence in arid areas. Two types of equipment have been designed and tested: a side delivery windrower, and an endless chain conveyor which lifts the brush residue over trailing seeding equipment and drops it on the seeded strip behind the planter. The side-delivery equipment was tested during planting tests in 1966 on several types of soils. Additional shielding equipment was found to be necessary to guide and place the brush residue onto the seeded strip. Preliminary field trials with the endless chain conveyor have been satisfactory and it is considered to be the better of the two types of equipment.

C. Cotton Seedbed Preparation, Planting and Fertilizing Equipment.

1. This project made significant progress in obtaining better stands of cotton through integrated systems of seed bed preparation and planting at several locations. Although equipment design varied to fit specific conditions, the basic principle of precisely shaping a seedbed with sled-type equipment, and planting with similar precision, resulted in better and more uniform stands at Stoneville, Miss., and Lubbock, Tex. Precision in the shape of the seedbed improved precision in placement and covering of seed. This resulted in uniform plant size; and the uniform beds contributed to more precision in the application of chemicals and to better harvesting efficiency.

At Stoneville, Miss., this year, a combination fertilizer applicator and bed shaping unit was developed and used satisfactorily on the carrier. This equipment was used in preparing shaped beds for subsequent precision planting and cultural operations. The planting unit consisted of a front-mounted cultivator equipped with Stoneville bed blades and rake-off wings and a double tool bar rear-mounted planter. The first bar was for support of knife injectors and spool type rollers and unit planters were mounted on the second bar. Although some modifications were indicated, the basic system looks promising.

Three years of tests show the drum planter to be superior to conventional planting equipment. This planter lends itself to adaptation to the sled-tool-carrier system. Compaction in the root zone was reduced by using a system of paired rows and a tractor-sled-carrier unit with wide-spread wheels.

Approximately 103 hours of temperature above 64°F are needed to obtain first emergence of cotton seed planted two inches deep at Lubbock, Texas. A good correlation also exists between minimum daily seed level temperature during the emergence period and total hours required for initial emergence. Field data indicates that soil aggregates in the covering soil smaller than 0.25 inches in diameter may have a positive influence on the rate of emergence.

The relationship of plant population and hill spacing was re-evaluated at Stoneville, Miss. By varying the hill spacing, from a minimum of one foot to a maximum of four feet, and controlling the number of plants per hill, information was obtained on the plant growth and its corresponding yield. It was noted that the wider spaced hills and fewer plants produced more cotton per plant than the narrow spaced hills with more plants. However, with the yield projected to pounds of seed cotton per acre, the wider spaced hills with fewer plants gave some of the lower yields. Hill spacing and number of plants per hill were found to significantly influence the diameter of the stalk.

D. Vegetable Planting and Fertilizing Equipment.

1. Four year summary of field experiments with vegetables in cooperation with the Florida station, showed yield increases of cabbage and cucumbers up to 9 percent with a two band fertilizer placement to the side and below plant or seed at time of planting, in comparison with broadcast application (common practice). Two band high-low side application (three and six inch depths) showed yield increases of green beans up to 20 percent. Rates of fertilizer (heavy, half and 3/4) showed no consistent production response. Several specially designed machines were provided - one vegetable unit now seeds or transplants, and may precision place or broadcast liquid or dry fertilizer.

During research cooperative with the Michigan station an experimental potato planter was designed and constructed in 1965-66 to study depth of planting, fertilizer placement, soil fertility, and the type and amount of compaction on the seedpiece to obtain maximum yields of quality potatoes. The 1966 results showed definite differences in the early stands by using a double "V" type press wheel; however, as the season progressed, these differences were not clearly measurable in terms of total yields. Total yields may not be a suitable measure of response since the plants surrounding skips in the row respond by developing large tubers. These tubers are often oversized, off-shaped and hollow hearted and are discounted and culled from the market.

Cooperators at the Western Washington experiment station report utilizing five of seven special seeding and fertilizing machines designed and constructed by AE. A study of sprinkler-irrigated potatoes ~~was~~ conducted to determine the effect of single rates of N, P, and K, (75-65-125 lbs. per acre) with the fertilizer application varied as to source and band placement. The best sources of N and K were Ammonium nitrate and Potassium sulfate. Fertilizer efficiency was improved by combining NPK materials in two bands, two inches to the side and level with the seedpiece, instead of one band.

E. Decontamination of Agricultural Land.

1. Radioactivity uptake studies were conducted at Bushland, Texas in 1966. Five crops were planted on each of three types of seed beds: (1) deep plowed (about 36 inches deep), (2) deep plowed with buried plant growth inhibitor, and (3) tilled with a rotary tiller. Strontium 85 radioactivity was sprayed on the plots before seed bed preparation. This isotope is taken up by the roots of plants. An additional area at the end of the plots was sprayed with gold 198, a cross section of which was examined by means of a trench in which soil samples were taken to determine the burial pattern. Samples of the crop were removed repeatedly during the growing season and radioassays made. The deep plowed crops showed about 17 percent as much activity as those in the rotary tilled plots, while crops in deep plowed plus growth inhibitor showed only 2 percent of the rotary tilled. A mechanical street sweeper was tested on both sandy and loamy soil fields. With nine passes, one inch of soil was removed and 100 percent decontamination was accomplished.

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Equipment for Establishment of Forages.

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Decontamination of Agricultural Land

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AREA NO. 3: CROP PEST CONTROL TECHNIQUES AND EQUIPMENT *

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the methods which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control. It is also time consuming and costly. It is believed that with sprayers and dusters now used, often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provides sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa, Columbia, Missouri, and Stoneville, Mississippi.

*Except electric, which is in Area 11.

Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington stations and ENT, on low growing crops. Pest control equipment research for certain crops is conducted: for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; Lubbock, Texas; and (particularly for boll weevil control) at State College, Mississippi; for vegetable crops at Forest Grove, Oregon; and for brush control at Mayaguez, Puerto Rico and College Station, Texas.

The Federal scientific effort devoted to research in this area totals 16.2 scientific man-years per year. Of this number 1.0 was devoted to basic studies in aerosols and spray formations; 0.6 to soil fumigation; 2.3 to insect control in grain; 2.9 to weed control in corn and soybeans; 3.5 to pest control equipment in cotton; 0.3 to insect and disease control by ground equipment in vegetables and other low-growing crops; 1.0 to insect and disease control by ground equipment to fruit; 1.6 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.2 to aerial spray equipment for forest insect control; and 1.8 to brush control equipment and methods.

PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 8.6 scientific man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Studies in Aerosols and Spray Formation.

1. At the present level of knowledge about transport and dispersion of fine particles and droplets suspended in a turbulent atmosphere, two important problems are: (1) how external forces, such as gravitational or electric fields, affect dispersion of the aerosol, and (2) how these processes are altered when the particles are very near a solid boundary surface. Under (1), dispersion studies were continued at the Pioneering Research Laboratory on Physics of Fine Particles at Wooster, Ohio, and a modified turbulent dispersion theory developed, which gave an adequate prediction of colloid

concentrations throughout a duct on the basis of the flow measurements. Under (2), a theory was developed to describe the random motion of particles suspended in a turbulent fluid for the case when initial particle velocity cannot be neglected. Experimental techniques were devised for studying the details of particle deposit patterns on solid surfaces.

Research in fine particle statistics was conducted with application of lineal analysis concepts to sizing of circular and irregular particle images with the aid of the AE Flying-Spot Particle Analyzer.

The following studies were made in cooperation with Ohio station: (1) developed statistical viscoelastic theory as a part of research on the strength relaxation properties of alfalfa stems, and (2) developed a proposed hydrologic theory to describe fluid flow over a random surface, based on particle motion conceptions.

B. Soil Fumigation.

1. Strips of soil were treated in 1957, in cooperation with the Ohio station, in an old cherry orchard before replants of sour cherries were set. Recent measurements show that trees grew much better and produced considerably more fruit in the treated soils.

Experimental equipment was constructed to apply granular and liquid insecticides broadcast or in the row and on the surface or mixed into the soil for control of corn rootworm larvae, cutworms, and webworm. Some insecticides used for rootworm larvae control produced increased yields. Generally, best results were obtained from insecticides incorporated in the soil. Cutworm and webworm control was inconclusive. More data is required on application equipment and techniques for control of these pests.

C. Insect Control in Grain.

1. Investigations for the control of the European corn borer, made in cooperation with the Iowa station, indicated that recommended rates of granular insecticides in pounds per acre gave adequate corn borer control regardless of plant spacing. Granular formulations continued to show better borer control than liquids. Granular insecticides at cultivation time resulted in good control of both corn rootworms and corn borers. Soil incorporation improved the rootworm control, but the kinds of tools used for incorporation or the amount of soil worked had little effect on control. Granules applied directly over the corn plant (recommended for borer control) were as effective for rootworm control as basal applications. Granular and liquid application equipment was modified to fit both 30-inch and 20-inch row widths.

High-clearance spray equipment was used to apply insecticides for the control of the adult corn rootworm in cooperation with the Ohio Station. High initial kills were obtained. Reinfestation apparently nullified this effect. Diazinon, carbaryl, and methyl parathion gave the highest initial adult kill. Single and repeated applications made in timing studies between

August 15th and 22nd did not produce significantly different results. Sprays applied to corn for flea beetle control gave significant reductions of infestation. Methyl parathion gave the greatest initial and residual reduction in beetle population but increases in corn yield were not significant.

2. An experimental low-volume sprayer was developed in Georgia which can apply one pint to one quart per acre. Using this sprayer on corn and soybeans produced results that compared favorably with those obtained from conventional spraying. A special fan trap was superior to a gravity trap when collecting eight species of insects. A field insect collector was developed for cooperating entomologists, and a Lepidopterous Larvae Dispenser for use in mass rearing of larvae for experiments. The use of ultrasonics appeared ineffective for control of the corn earworm. Orienting seed at planting did not improve insect control in corn.

D. Weed Control in Corn and Soybeans.

Several systems of mechanical cultivation were evaluated for weed control in corn, in cooperation with the Iowa station. A dragging rotary hoe used to till a band 15 inches wide over the corn row was more effective than the rotary hoe. Harrowing after planting improved weed control best of all mechanical cultivating systems used. Shallow cultivations (rotary hoe or dragging hoe) when performed separately were most effective when weeds were at the two-leaf stage. A dragging hoe used with the first sweep cultivation (4- to 8-leaf stage) eliminated the need for early shallow cultivations. Weeds in the row must be controlled if maximum yields are to be obtained.

Equipment studies, in cooperation with the Missouri station, show that dalapon can be applied on corn if nozzles are arranged to prevent the spray from contacting the corn leaves. Linuron (two pounds per acre) was more effective with a directed sprayer when the corn was 12 inches high. Dinitro (three pounds per acre) can be used as a postemergence herbicide in six-inch high soybeans if spray is directed to the lower stems of the plant. Preemergence herbicides applied in eight-inch bands are as effective as those in 16-inch bands. In low volume preemergence applications (.5 to 5 gpa) of herbicides, trifluralin is more effective than amiben, and an air atomizing nozzle is better than a fan nozzle. Studies of spray distribution and atomization qualities of low volume nozzles showed less than five percent spray coverage, with spray losses from 10 percent to 90 percent.

Grass seed was subjected to treatment in a dielectric heater, in Mississippi, to determine effect of high frequency electric waves on germination. Frequencies of 67 to 80 megacycles and 2,450 magacycles were used. All seed was killed with exposure time of six seconds or more in the lower frequency range. No effects were observed at the higher frequency. Plans were made to treat weed seed over a wide range of frequencies of electrical waves to determine effects on germination.

2. Several herbicides were applied to field corn, in cooperation with the Iowa station, before and after planting using liquid and granular formulations that were incorporated into the soil with various tools. Chemical applications gave better weed control and higher yields than cultivated checks. Sprays were as effective as granules. Soil incorporation did not materially improve weed control with any chemicals; however, cultivating action of the incorporating tools without chemicals did improve weed control. Similar tests with soybeans showed liquids as effective as granules and weed control obtained with mechanical cultivations as good as that obtained with most chemicals.

Field studies were made in cooperation with the Missouri station, to evaluate equipment for incorporating trifluralin (one pound per acre) and amiben (one and two pounds per acre) with the soil for weed control in soybeans. Trifluralin performed best with a power rotary cultivator. Disk harrow plots had better weed control than check plots but not as good as power rotary cultivator plots. Laboratory studies were made to determine the distribution of trifluralin in the soil when incorporated with the power rotary cultivator and the disk harrow. Gas chromatographic analysis of soil samples showed that the power rotary cultivator concentrates the trifluralin in the upper inch of soil while the disk harrow concentrates the trifluralin at about two-thirds of its operating depth.

E. Pest Control Equipment for Cotton.

1. Chemical weed control equipment studies continued at Stoneville, Miss., and Auburn, Ala., devoted primarily to incorporation and injection of herbicides. At Auburn, field incorporation studies were conducted to determine the most satisfactory time to apply and incorporate trifluralin in relation to planting. Trifluralin applied and incorporated with a disk harrow up to 30 days before planting gave good weed control and did not affect the yield or stand of cotton. Varying the amount of water from 7-1/2 to 45 gallons per acre when applying and incorporating trifluralin with a power-driven rotary tool gave no difference in weed control. These results are in agreement with those of 1965. At Stoneville, two herbicides were incorporated in the soil with a power-driven rotary tillage unit and a disk harrow in both fall and spring treatments and were compared with a band treatment which was applied at planting time with a double reel incorporator. All treatments gave good weed control regardless of rate, date, or method of incorporation.

Depth of incorporation and tools for incorporation were studied for the third year at Auburn. Incorporating trifluralin from one to five inches deep did not affect weed control. All depths of incorporation gave better weed control than no incorporation. Of five tools used to incorporate trifluralin, all were equally effective in the control of weeds. These results are in agreement with those of two previous years.

Development of integrated planting and herbicide equipment was continued primarily for evaluation of herbicides at Stoneville. Three types of liquid

herbicide subsurface applicators were compared with a surface applicator for controlling weeds in cotton. The subsurface applicators included soil incorporators, knife injectors, and subsurface sweep-type applicators, while the surface applicators consisted of a conventional drop nozzle mounted behind the planter presswheel. Field tests indicated that crop tolerance and control of specific weeds are definitely affected by method of application. There was a drastic reduction in injury to cotton plants when certain herbicides were injected in the soil as compared with incorporation or surface application. Soil incorporation, soil injection, and subsurface application were superior to surface application with respect to cocklebur control.

In post-emergence control studies at Stoneville, EPTC (ethyl N,N-dipropylthiolcarbamate) injected on the row shoulders at three inch and six inch plant heights and at several rates resulted in no significant differences in seed cotton yield. However, the three and six pound per acre rates applied twice at the three and six inch stages of growth indicated that yield would be adversely affected by the higher rates.

In comparing methods of seedbed preparation for replanting following early application of EPTC, the Stoneville bed blade and an experimental rake-off blade gave minimum soil disturbance and best results. Disking and rebedding the EPTC-treated beds gave severe early injury to cotton but did not significantly reduce yields. These results indicate that mixing the soil in an effort to dilute the EPTC before replanting is undesirable.

Post-emergence applicators were studied in skip-row cotton at Stoneville. A four-row sled tool carrier equipped with 24-inch subsurface spray applicator sweeps was used in both mechanical and chemical control of weeds in plant four, skip four, skip-row cotton. Chemical control was somewhat erratic but excellent control and a smooth surface was maintained with the sweeps alone.

2. At Lubbock Texas, pre-emergence herbicides again gave better control when applied to cotton planted on beds than when applied to cotton planted in the lister furrow.

Preliminary studies using ultra-low-volume insecticide application equipment were made in 1966 at Auburn. Test results indicated that the volume of spray material applied per acre may be reduced to as low as 16 ounces per acre when concentrated technical chemicals are applied with ultra-low-volume spray equipment. The study also showed that more information is needed on distribution, calibration and drift.

3. In insect control, work was continued on boll weevil control with the Entomology Division at the Boll Weevil Research Laboratory at State College, Miss. Field tests with the flail machine for destroying fallen cotton squares were conducted to determine the boll weevil control obtainable mechanically. Pickup efficiency for the season varied from 88.1 percent to 100 percent, with a mean of 95.3 percent. Soil surface moisture appeared

to have more effect on efficiency than surface roughness. The tests indicated that control could be maintained as long as weather and plant growth conditions permitted regular machine operation.

The rotary disc sprayer for applying ultra-low-volume concentrates at State College was improved by modifications made this year. The ULV applications gave better boll weevil control than conventional applications, using Guthion as the insecticide.

F. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops.

1. Equipment was prepared to meter and apply four different undiluted liquid insecticide formulations, in cooperation with the Ohio station, to vegetable crops at dosages from six to twenty-four ounces per acre. Control of green peach aphid, turnip aphid, two spotted mites, and imported cabbage worm was obtained by some of the different insecticide applications. Orchard sprays containing wettable powders at 33 to 66 times normal concentration in water were applied to apples at 0.12 to 0.24 gallon of spray per tree. Dormant oil spray was applied at 0.16 gallon per tree. Control of apple scab, European red mite, rosy apple aphid, codling moth, red banded leaf roller, and plum curculio was obtained.

Electrostatic charges were applied to dust: when dusting mint with a commercially available charger/duster, when dusting hops with a modified commercial duster, and when dusting broccoli and Brussels sprouts with a research duster. Results were inconclusive with all electrostatic charging. An automatic plate washer for aircraft spray distribution tests was developed, tested, and modified, and the operation was satisfactory. The OSU research sprayer/duster was modified to make a duster with a three-point hitch, and having simplified boom mounts.

G. Insect and Disease Control by Ground Equipment for Fruit.

1. Equipment was developed and briefly tested, in Washington, for use in mass rearing and releasing sterile male codling moth to control native infestations. Equipment included: (1) pupae sex separating machine, through size difference between sexes, using gradual larger space between two rotating incline rolls; (2) electronic sorter for separating mature from other pupae by reflection difference in infrared region; and (3) flight mill for determining vigor of moths exposed to gamma radiation - a photoelectric counter records rotations of moth attached to a pivot arm flying in horizontal circle.

Undiluted spray chemicals applied at one pint per acre on potatoes using pressure nozzles on ground machine were ineffective in controlling green peach aphid.

H. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. The third series of tests were completed in Oregon on boom location for helicopter spray distribution studies. These tests included: (1) ultra-low-volume (ULV) nozzle temperature studies, (2) Forest Grove electric Minispin nozzles which were fabricated and bench-tested, (3) vibrajets nozzles which were tested and found unsatisfactory because of mechanical problems in aerial use, and (4) Plant Protection Ltd. orifice plates which were tested for the drop size spectrum. Cooperative spray studies were conducted with ENT: (1) pole beans were sprayed with malathion against the black aphid with helicopter vs fixed-wing aircraft, first results favor the helicopter; (2) lima beans were sprayed with ULV malathion in a single test for a processor with results satisfactory; and (3) broccoli was sprayed against the cabbage looper for a processor with results satisfactory. Cooperative studies were conducted with the U.S. Forest Service and a tree sampler for use from a helicopter was designed, made, and put into field use.

2. In a research project conducted under contract with the Mississippi station on equipment for application of agricultural materials from fixed-wing aircraft, the major effort has been concentrated on: (1) development of a positive-energy system for the distribution of solid materials, (2) study of the behavior of small spray particles in complex flow fields, and (3) feasibility study to determine the requirements of agricultural aircraft possibility for future designs. In the positive-energy study a full scale fluted rotor engine-driven metering device was constructed on the basis of the results of previous model tests. This was tested in the laboratory and also was ground tested after installation in the aircraft. In the small particle study, a device was constructed and tested which is capable of generating small uniform liquid particles and has the capability of isolating a single generated droplet for observation. Particle formation phenomena have been photographed. A previously reported digital computer program (for analysis of flight test data and for manipulation of flight parameters) has been converted to an analog computer program to permit continual variation of the characteristic parameters in order to determine the effect of this on the aircraft operating productivity.

I. Aerial Spray Equipment for Forest Insect Control.

1. Previous work at Beltsville, in cooperation with the Forest Service, indicated that electrostatically charged spray released from aircraft, generates a large residual charge on the airframe. The effects of this phenomena was investigated theoretically and proven experimentally. Results of this exploration led to a study of three techniques under which sprays might be electrically charged: technique of polarity reversal, dual power supply technique, and gaseous ion emission. Work was started on a technique to electrically atomize a low volume aerial spray.

J. Equipment for Brush Defoliation.

1. Research was continued in Puerto Rico and Texas in cooperation with CR, on equipment and techniques for applying herbicides to vegetation. One hundred and eighteen spray penetration tests through a dense tropical vegetation on a cableway system over a tropical forest canopy near Maricao, Puerto Rico, were completed. Hollow cone and fan type nozzles were tested at speeds of 10, 15 and 20 mph and pressures of 10 to 40 psi. An automatic electronic weather station recorded air temperature, dew point, wind velocity and direction, and precipitation. The test area, 260 feet x forty feet, contained 1,000 woody perennials ranging from 3 feet to 75 feet tall. Spray penetration samples were collected on 272 white cards at 1, 10, 25 and 40 foot levels above the forest floor. From one to three stories of vegetation were present. Penetration of only a few feet was observed through an unbroken canopy. Breaks in the canopy even though sparse permitted penetration to ground level. Isothermal air currents on mountainous terrain were an important factor in spray deposition. An average of less than 50 percent of the spray leaving the nozzle reached the top of the canopy. Penetration to the three lower levels was on the order of 60, 35 and 20 percent of the top level.

Aerial spray penetration in Texas through a multistory foliage canopy of post oak and yaupon was measured with sampling stations supported at heights of 43 feet, 17 feet and 2 feet. Non-toxic water spray and spray particulated with an insoluble polymer were applied through Floodjet, Hollow Cone, and Solid Jet nozzle tips. Invert emulsion was applied through a bifluid nozzle system. Three nozzle orientations were tested. Applications of four gallons per acre were made with a fixed-wing aircraft equipped with a trailing-edge boom. Nozzle orientation appeared to have different effects on penetration for the various nozzles and spray materials. Differences in spray penetration through the post oak canopy ranged from 19.4 to 22.5 percent and penetration through both canopies ranged from 4.2 to 6.6 percent. Water spray produced more and smaller drops with smaller standard deviations than equal volumes of particulated and invert emulsion sprays. Hollow Cone nozzles and Floodjet nozzles produced more drops than the solid Jet nozzles. The drop-size distribution was dependent on nozzle angle, nozzle type and spray material. This work for the Department of Defense in Puerto Rico and Texas, on equipment and techniques for brush control, was terminated March 30, 1967.

K. Foreign Research Under Public Law 480 Funds.

1. Tests were continued in Rehovot, Israel on a three-year research grant to improve the penetration of insecticide spraying into the dense foliage of citrus trees by use of air jets. Tests were made in the laboratory and field on influence of the swirl on penetration and distribution of spray. Results from regular jet using turbulent air issuing from a round orifice into the air were compared with swirling (or vortex) jet in which the swirling motion is introduced before it leaves the orifice. Some of the results include: (1) cross-section of the spray deposit pattern delivered

in tree by regular jet is not uniform - a narrow central strip is heavily overdosed and outer parts lack sufficient coverage; (2) swirling jet improves distribution by depositing higher rate of material along edges of the cross-section; (3) swirling jet does not penetrate deeper than regular, but improves the overall penetration in the tree row; (4) fall-out was higher with the regular jet, under all conditions; (5) relative run-off was higher with regular jet; (6) various nozzle arrangements at jet orifice had no noticeable effect on either fall-out or run-off from either types of air jets; and (7) power requirements of swirling jet with 45° pitch angle are 40 percent higher than regular jet.

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AREA 4: CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting crops and for handling of farm crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, relatively recently initiated, has already resulted in sizable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; and Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Equipment for cotton harvesting is under study at State College and Stoneville, Mississippi; Auburn, Alabama; Lubbock, Texas; and Shafter, California; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots, plums, grapes, blueberries, cherries, and dates. Research on mechanical coffee harvesting is conducted in cooperation with the Hawaii Experiment Station. Development of new techniques for harvesting forage is underway at Tifton, Georgia, in cooperation with the Georgia Experiment Station. Research on forage seed harvesting is underway at Corvallis, Oregon, in cooperation with the Oregon Experiment Station, farmers, and industry. Research on oilseeds and peanut harvesting equipment and methods is cooperative with the Experiment Stations at Bogalusa, Louisiana (tung

nut); Holland, Virginia (peanuts); and Tifton, Georgia (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. Equipment and methods for harvesting sugarcane are under study at Belle Glade, Florida, in cooperation with the Florida Experiment Station. Tobacco harvesting research is conducted cooperatively with the Experiment Station at Lexington, Kentucky.

A 3-year contract is underway at Louisiana State University for research on mechanically removing tops and leaf trash from sugarcane. Contract research is also underway at Virginia Polytechnic Institute for study of equipment and methods for farm curing and drying of Virginia-type peanuts and at the Georgia Coastal Plain Experiment Station for determination of location, nature, and extent of losses and damage occurring in peanut harvesting and farm handling. A research contract was continued with Clemson, Texas A&M, and Mississippi State Universities to determine the effect of mechanical harvesting, handling, and ginning on the germination of cottonseed.

The Federal engineering effort devoted to research in this area totals 25.4 scientific man-years. Of this number 5.0 are devoted to citrus and sub-tropical fruit; 4.6 to cotton; 5.3 to deciduous fruit; 0.3 to forage; 1.5 to forage seed; 3.7 to oilseeds and peanuts; 1.0 to potatoes; 2.0 to sugarcane; 1.0 to tobacco; and 1.0 to corn.

PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of the many economic crops which make up the total national agricultural production. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality, and overall efficiency.

Current research is concerned with the diverse problems involved with these specific crops: All small grains, including rice and field corn; cotton, peanuts, castor beans, and safflower; citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grapes and pecans; green-cut forages, hay, and seed crops; cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes; blueberries, peas and sweet corn; tobacco; and sugarcane.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 41.8 scientific man-years of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Citrus and Sub-Tropical Fruit Harvesting Equipment

1. Harvesting Citrus. The decreasing availability of suitable labor for picking citrus has created a serious need for improved methods and equipment for harvesting citrus fruits. Cooperative research with the Florida Citrus Commission and the University of Florida Citrus Experiment Station was continued with headquarters at Lake Alfred, Florida. Research in California in cooperation with the University of California, growers, and manufacturers, was continued with headquarters at Riverside. Tree shape and density determine many of the design factors in developing harvest equipment. Alteration of tree properties such as surface contour, skirt height, limb structure, and foliage density might simplify the control functions necessary on a machine or improve the effectiveness of the machine operator through improved visibility. In Florida tree pruning for the shaker-catch frame harvest system is in its second season. Results indicate less tree injury from the tree shaker, slightly increased fruit removal, and more trees shaken per hour. Data will be taken one more season in this phase of the project. A search for dwarfing rootstocks and effective growth retardants are also part of this research program in California. Removing dead brush from the tree will reduce fruit injury and decay caused during mechanical harvest. Modification which would minimize the number of major limbs in a tree has not been evaluated due to unavailability of trees. Also, modification which would minimize the amount of "interior" fruit has not been possible for the same reason. Investigations of both of these possibilities will be made next fiscal year.

2. A means of inducing abscission of some varieties of citrus fruit would increase the fruit removal capabilities of most experimental harvesting machines. The machines could also work as well at the early part of a varietal season as at the end. Intensive work was done by the Florida Citrus Commission (FCC) on the application of ethylene gas to mature citrus trees and greenhouse plants. Results were excellent for fruit abscission but unpredictable in terms of leaf abscission and root damage when soil injection methods were used. Ethylene gas is already cleared by Food and Drug Administration for citrus degreening and would be ready for immediate use in abscission if a satisfactory application method could be devised. A number of active double-bond chemicals were screened for abscission qualities as well as some halogenated salts that might prove as successful as the iodoacetic acid reported on previously. Additional contract research, administered by this project with the University of Florida, Fruit Crops Department, will be continued on the basic mechanism which causes abscission and screening of chemicals for abscission properties. In California, a greenhouse has been erected for conducting studies on the effect of electric currents on citrus trees. It has been found that placing copper or silver

electrodes in the tree will kill surrounding plant tissue and the entire branch, in some cases. Stainless steel has not produced this toxic effect. Stimulated growth, related to electrical currents, has not been observed. Previous results of stimulated growth or abscission have not been substantiated in recent tests, although they may be in the future. Over 40 chemicals have now been applied to trees in field tests. Only navel oranges have shown a significant response. Ethylene, potassium iodide, naphthalene-acetic-acid, iron, and Cumeran have shown strong to weak effects on reducing the attachment force as measured by a straight pull test. In recent limb shaking tests, KI and NAA resulted in fewer fruit with stems attached but did not increase the percent of fruit removed from the tree, which averaged 93 percent.

3. In Florida the 5-year program to study the cumulative effects of citrus tree shaking on fruit yield and tree vigor is in its fourth season. Results to date look very good in early and mid-season orange varieties and grapefruit but Valencia oranges experience a drop in fruit yield the season following tree shaking due to excessive removal of the small green fruit during harvest. A "snapping shaker" is being developed which may differentiate between large mature 'Valencia' oranges and the small green fruit of next year's crop. A prototype tree shaker harvest system was built by the FCC at this location and has been used by two fruit companies in their groves harvesting mid-season oranges. Four tractor mounted inertia-type tree shakers have been built by growers using plans and design data developed in this project. Using these shakers, the growers are shaking fruit onto the ground for hand pick-up. Work on the oscillating air blast harvest system was terminated this season because one manufacturer has built a prototype system which should be in use next season. In California analysis of limb shaker tests in Valencias and navels, reported last year, was completed. Fruit shaken from trees sprayed with 2,4-D, to tighten the fruit, had twice the decay of fruit shaken from unsprayed trees and about 1.4 times the surface injury. These studies also indicate that citrus varieties not having two crops on the tree at harvest time can be successfully harvested for processing if techniques developed by the Florida Project are applied. Methods of canopy shaking have been investigated in an effort to remove the fruit quickly and thus decrease damage. Fruit can be removed quickly by this method. Levels of damage have not been evaluated yet. Further work with vertical pulsating air for fruit removal was discontinued. Investigations may resume at a time when additional personnel are available, or other projects permit.

4. Mechanical Citrus Pickers. In Florida, development work continued on the auger-type picking spindles which contact the fruit when projected into the tree and twist it off. Two new auger shapes were tested which were not as successful as those tested in FY 66. Limited picking trials indicate that 60 to 70 percent of the fruit is removed with the present equipment in a picking time of 15 to 20 minutes per tree. This harvest method looks desirable in Valencia oranges where the augers contact the larger fruit and leave the small fruit of next year's crop. A new positioning mechanism is being built and a larger bank of augers will be built for more extensive trials.

Seven other machines belonging to private individuals or companies were evaluated. These units either strip the fruit off by raking through the tree or snap it off with rollers. None of these machines appeared economically feasible at the present time. In California, a single vacuum twist device was constructed and mounted in a positioning frame designed to hold nine similar devices. These devices can penetrate the tree canopy in a pre-set grid or be controlled by fruit sensors being developed. The equipment was field tested only enough to check the operation of the positioning frame. A complete field test will not be conducted until the devices are equipped with sensors. A fruit harvesting head using spinning rollers which comb through the tree canopy and harvest fruit by a snapping action was constructed and tested in navel and Valencia oranges. In the navel test, about 80 percent of the fruits were removed at or below the button and plugging amounted to about 1 percent. Nearly all fruit in the path of the rollers was removed. In the Valencia test, the roller head and 'Florida Auger' head were compared. Both experimental units harvested about the same percent of the fruit on the trees. About 70 percent of the fruits were removed at or below the button. Plugging was 0 percent for the auger and 2.8 percent for the roller. Fruit surface injury and decay was similar for both units. The level of injury was much less than that experienced in limb shaking tests but the percent of fruit removed from the trees was only about 50 percent for both units. Work continued on developing a rugged, sensitive, and inexpensive fruit detector for use with the vacuum twist harvesting head. A detector using photocells, and capable of compensating for different natural light levels was constructed and tested. A prototype for field use is being designed.

5. Citrus Picking Aids. In California, the electro-mechanical power clipper designed last year was discarded after brief testing because of inherent operational problems. A pneumatic operated clipper was developed. Its cut is satisfactory, it is light weight, compact, and easily handled by the picker. The jaw design must be improved to allow easier engagement of the fruit stem before the field tests are conducted. The Power Ladder, mechanical man-positioning device, reported on last year has been redesigned by the manufacturer to allow bulk handling, working in taller trees, and improved mobility. One machine has been sold for avocado picking. Studies of human energy expenditure for hand picking citrus were conducted by a University cooperator for general picking and the component tasks involved in general picking. This identifies the 'hard' tasks. It was found that (1) carrying and setting the ladder requires nearly twice the energy per unit of time that general picking does; (2) pickers are 25 percent more efficient when picking ground fruit than during general picking; (3) picking fruit from the ladder is not appreciably less efficient than general picking. In Florida a mechanized picking platform for tree wall plantings of citrus is being tested. Preliminary picking data in a small number of trees shows no increase in picking rate in man-minutes per box but more extensive trials will be run as the fruit yield in the drastically pruned "tree walls" increases. Several fruit pick-up machines are being developed. A vacuum-type single hose machine was built and tested. A machine developed by AERD for picking up tung nuts is being modified to pick up citrus that has been hand picked and dropped or shaken onto the ground.

6. Coffee Harvesting. Coffee harvesting labor outside of the farm families is practically nonexistent in Kona, Hawaii. Since harvesting accounts for over 70 percent of the total farm labor input for coffee production the growers income is limited by the amount of coffee the farm families can harvest. Acreage has declined sharply and mechanical harvesting methods must be developed if the industry is to survive. A circular motion shaker was constructed and field tested. Vibration transmission perpendicular to the shaker arm was better, and cost was less, as compared with the linear shaker. A modified inverted umbrella and a filing cabinet type of collector were constructed. Maneuverability and pneumatic conveying were improved with the inverted umbrella unit. Mechanical problems prevented obtaining conclusive results with the filing cabinet-type collector. Rigid-frame hand-carried collectors were successfully used in orchards with relatively even ground and uniformly spaced trees. However, drop-cloths were more satisfactory for conditions found in many Kona orchards. The following picking aids were built: (1) A hand held, balanced, reciprocating shaker; (2) a limb hung, inertia type shaker; (3) a pair of rotating, parallel, cylindrical brushes. A commercial, hand held, reciprocating shaker was obtained. Preliminary tests of these picking aids indicate that all may have excellent possibilities. A test plot was severely pruned to alter existing trees for mechanical harvesting. Results will not be available until sufficient regrowth occurs. Laboratory equipment has been assembled to study the relation between internal damping and vibration transmission. Laboratory results will be compared with theory. Because selective harvesting of ripe fruit has been inadequate, post harvest separation methods are being developed. Preliminary fruit bouncing studies show sufficient differences between ripe and green fruit to warrant further investigation. Another method uses two rollers with a tapered space between them to separate fruit by minor diameter differences. Other possibilities will also be explored.

7. Pollinization of Dates. In the past all commercial date production areas of the world pollinated the female date blooms by some hand method. Because of the shortage of labor and the fact that the harvest is now 100 percent mechanized with methods and equipment which were developed on this project, hand labor is not available for pollination. An experimental pollination program was initiated last year using both fixed-wing and helicopter aircraft to apply pollen in a dust form. All fruit produced in 12 aerial pollination plots was mechanically harvested under the supervision of project personnel. Preliminary analysis of results indicate that in several of the aerial plots the production of pollinated fruit was at least equal that of hand pollinated checks. The amount of pollen required for aerial application may be no more than for hand application but the viability should be as high as possible, i.e., good handling and storage practices are required. Because of the promising results and lack of laborers for pollination the date industry has contracted for 500 acres to be pollinated entirely by helicopter this season using the methods and equipment developed so far. In addition to the commercial acreage, four 10-acre blocks will be involved in additional application rate and frequency tests. We will also attempt to refine the application technique so that results will be improved.

8. Date Pruning, Tying etc. Dethorning, pruning, tying, and bagging are necessary operations in date production and the required labor is not available. Time studies for the tiedown operation were conducted on crews using ladders to enter the palms and using a harvesting tower to place men in the palms. Seventy-five percent of the ladder crews' time was spent in the palm tying bunches. The harvesting tower was not as efficient as the ladders and resulted in an increase in labor requirements. Some towers are used in this operation, however, since not all of the available workers can handle the tall ladders. A support ring, made in sections, so it could be placed in the palm crown, was built and tested in an attempt to eliminate the necessity of tying each bunch to a frond stalk for support. A limited test was encouraging and various ring designs will be tried in an attempt to develop one which is inexpensive and easily installed. Time studies of the summer pruning and bagging operations were conducted. A pruning test using power saws was run. Possibly a harvesting platform designed so that power saws can be used and bags applied from the platform will decrease labor requirements and cost for this operation.

B. Cotton Harvesting Equipment

1. In a study of the effects of topping and lateral pruning on plant lodging, picking efficiency, boll rot, yield, microclimate, and cotton quality at Stoneville, topping alone did not affect yield. However, side-pruning and a combination of topping and side-pruning on August 24 resulted in a highly significant yield reduction. Picking efficiency was not affected by topping or side-pruning. All topping and side-pruning treatments resulted in a slight increase in grade. Plant lodging was not a problem in 1966 and boll rot was negligible.

A harvest aid study included undefoliated, partially defoliated, partially desiccated, desiccated, and well-defoliated treatments on D&PL Smoothleaf and Stoneville 7A cotton. There were no significant treatment effects on cotton yield, composite grade, picking efficiency, stalk and ground loss, fiber strength, foreign matter content, Micronaire, uniformity ratio, reflectance, and upper half mean length. The desiccated treatment produced significantly more trash in the seed cotton sample than did the well defoliated treatment. The well defoliated treatment had significantly less yellowness than the other treatments. D&PL Smoothleaf showed significantly less trash in the seed cotton and lint samples than did Stoneville 7A. D&PL Smoothleaf was significantly lower in Micronaire, strength and length; and significantly higher in composite grades and reflectance than Stoneville 7A.

In a related study, comparison of three different systems of defoliation and harvesting including (1) stratified (bottom defoliation and bottom harvesting), (2) conventional (defoliation at 60-70 percent open bolls), and (3) delayed (once-over harvesting preceded by desiccation or frost) revealed no significant difference between any of the three systems based on gross dollars returned per acre. Thus the chemical aids did not pay either for themselves nor for their cost of application in 1966.

A wilt harvest test at Shafter compared defoliated, desiccated, chemically-induced wilting and a non-treated check. Harvested seed cotton moisture was lowest for defoliation followed by desiccation. Lint moisture before harvest was also lower for these two treatments than the wilt treatment and check. Trash content was lowest for defoliation and highest for desiccation. Classer's grades showed an advantage for defoliation and a reduction for the wilt treatment due to color. Defoliation gave highest picker efficiency under rank growth conditions. The conclusion is that there is little reason to use wilt-harvest except under emergency conditions.

Similar tests at Stoneville comparing the effects of two types of wilting agents with defoliation and an undefoliated check showed that harvested seed cotton trash contents were significantly higher for all of the chemically treated plots than from the check. Although yields were significantly higher for one of the wilting agents, the cost of the agent at the rate which was applied prohibits its being recommended. No fiber quality tested was affected by any of the treatments. Efforts to reduce the rates of application of the wilting agents will be included in 1967 tests.

2. Trash reduction efforts at Stoneville included the design and construction of a series of fingers fitting between the picking zone and the doffers in a spindle type picker. Highspeed movies with the laboratory picker and observations in the field indicate there is not enough air velocity at this point to expel the trash removed by the fingers. Air nozzles were designed and tested at several pressures in an attempt to blow the free trash out of the picker head. The combination of fingers and air nozzles resulted in a considerable reduction in seed cotton trash content after harvesting. Both devices will be field tested in 1967. Also, for better trash removal, three basket grates were constructed for a John Deere 99 two-row picker and were compared by field tests with conventional grates. Average seed cotton trash contents were 1) 4.52 percent for the grate made of rearranged expanded metal strips, 2) 4.92 percent for the grate made of 1/8- by 1/2-inch flat strips, 3) 5.32 percent for the grate made of 1/4-inch round stock, and 4) 5.41 percent for the conventional grate. The differences in seed cotton trash were not apparent after ginning. All experimental grates had more buildup of seed cotton during picking.

3. Spindle parameter studies were continued on the laboratory model cotton-picker and in the field with standard pickers at Auburn. Field efficiencies of 3-barb, 6-barb, new 14-barb, and worn 14-barb spindles were 87.8 percent, 88.4 percent, 89.5 percent, and 89.6 percent, respectively. Spindle barb measurements showed a large difference in barb wear between spindles of the front and rear drums and among spindles within each drum.

4. In studying factors affecting removal of cotton from the bur, three lock removal experiments were run at Stoneville this year. Force, energy, and distance required to remove cotton locks from the bur were measured using greenhouse-grown bolls which had not been subjected to inclement weather. Independent variables recorded included 1) boll location, 2) bloom date,

3) open date, 4) open-boll exposure period, and 5) environmental conditions while measuring dependent variables. Much of the variation in force, energy, and distance measurements could not be accounted for by correlation analysis. Variables which were significantly related to peak removal force on a per-boll basis included 1) carpel angle, 2) branch number, 3) open date, and 4) exposure period. Energy measurements were significantly related to 1) branch number, 2) lock weight, and 3) seeds per lock. At Auburn, field and laboratory data were obtained for the third year from 13 varieties varying greatly in genetic character. Curves plotted from picking energy measurements versus field losses were similar in shape but differed in magnitude to the 1964 curves. As in previous years, storm resistance was an important factor affecting field losses. Weather losses among varieties varied from 1.9 percent to 8.0 percent for twice-over picking and 1.2 percent to 20.0 percent for once-over picking. Total field loss varied from 7.0 percent to 12.8 percent for twice-over picking and from 10.7 percent to 24.6 percent for once-over picking. Numerous plant character and picker performance measurements were investigated for correlations with each other.

The effect of yield on mechanical cotton pickers was observed in the laboratory at Stoneville with the use of a highspeed movie camera, torquometer, and efficiency measurements. Varying yields from 0.6 bale per acre to 6.3 bales per acre were constructed by inserting or removing whole stalks as necessary in the boards for the laboratory picker. No differences in efficiency were observed. High-speed movies showed that still higher yields could be picked and still remain above the 90 percent level of efficiency. Torque varied as the yield, although the major portion of the torque required--below 3 bales per acre--was needed to turn the picker head.

The effects of hill spacing on harvesting efficiency were re-evaluated at Stoneville. Variables in hill spacing, plants per hill, plant diameter, and plant height had little or no direct effect on picker efficiency. Yield was the principal variable affecting efficiency. Additional biological research relative to varietal as well as boll-characteristic effects on machine performance will be continued.

5. An experiment was run on the effect of Alpha, Beta-Dichloroisobutyrate on boll set and fiber properties of Stoneville 213 cotton to determine if early and late-season boll shed could be induced in a cotton plant with chemical application. The effect on fiber quality and yield were also of interest. Significance of this study from a physiological and engineering standpoint is that if fruit set can be limited to a shorter time interval without adverse effects on yield and quality, then a once-over harvesting system could be developed. The experiment consisted of a randomized block experiment with 6 treatments and 5 replications. There was some evidence of early shedding of bolls; however, there was more evidence of late bolls set in these treatments. The one late application showed no evidence of causing late boll shed. Experiment data showed differences in yield and fiber properties. Results also showed time of application as being critical.

Stripper harvester studies were conducted at Auburn and Lubbock. On the experimental narrow-row harvester at Lubbock, a grate with a higher percentage of opening under the cross auger has increased the amount of small trash removed. The addition of an automatic header control provides a more accurate method of controlling position of the header. At Auburn, a comparative test of stripper harvesting and spindle picking was conducted in cooperation with the Southeastern Cotton Ginning Research Laboratory. Field data are in close agreement with those from the 1965 test. The picker overall harvesting efficiency (twice-over) was 91.6 percent as compared with 88.9 percent for the stripper. The picker harvested 1853 pounds of cotton per acre with a trash content of 5.7 percent and 1747 pounds of clean seed cotton. The stripper harvested 2408 pounds per acre with a trash content of 27.6 percent and 1743 pounds of clean seed cotton.

6. In handling and storage studies at Stoneville, two baskets, 8 x 8 x 4 feet were constructed of metal at a material cost of approximately 36 dollars each. The design initially featured sides and bottoms of wire mesh and basic framework of angle iron. The baskets were supported by one roller located on each end of the basket just above the center of gravity. Each basket, when fully loaded (1-bale), could easily be pushed by hand along strips of channel-iron rails. Cotton was dumped into a 1-bale capacity hopper-feeder combination (located at the gin) by rotating the basket to an up-side-down position. In the first trial, an excessive amount of cotton remained entangled in the bottom of the basket. Consequently, one basket was modified to feature a trap-door bottom made of two pieces of expanded metal. Dumping is now possible without rotation. At Lubbock, studies indicate that hay balers will not do an adequate job of baling seed cotton. The bale density is too low and the bales will not take rough treatment. Laboratory studies show that a bale density of 20 to 25 pounds per cubic foot will not significantly crack seed. A pressure of 50 to 70 pounds per square inch is required to obtain this density.

7. Cottonseed damage was studied under a contract at Clemson, South Carolina; State College, Mississippi; and College Station, Texas. At Clemson, a relationship between seed damage, days of field exposure, and moisture content is being identified. Seed impact tests at State College have indicated that a decrease in germination occurs at certain intermediate impact velocities, then an increase in germination as impact velocity increases. Hypotheses were tested, and it was concluded with reasonable assurance that this dip in germination is related to the force transmissibility characteristics of the connection between the seed coat and the embryo. The relationship of field exposure to storability of seed cotton is being studied at College Station, Texas.

C. Deciduous Fruit Harvesting Equipment

1. Orchard Grading Apples. Growers store millions of bushels of apples "orchard run." A large proportion of undergrade and defective apples are stored in Controlled Atmosphere Storage (CA) and regular storage and then

sorted out and sent to cider mills or other low-return outlets each year. The mobile orchard grader trials reported on in FY 66 were completed. The results show that field sorting improved the grade of the fruit stored and reduced packing and storage costs. However, it now seems unlikely that the method will come into widespread use because it requires additional help during the harvest--a time when workers are in extremely short supply.

2. Harvesting Apples for Fresh Market. Apples for fresh market must be picked without bruising the fruit and must be harvested at optimum maturity for long time storage. Labor is not available to do this and machines and/or methods which will reduce labor are needed. A comprehensive time and efficiency study comparing four machine-assisted harvesting methods and the conventional ladder-bag system was made. The results indicate that further refinements in fruit and bin handling and machine positioning will result in additional small increases in the harvest rate. Improved fruit quality can be obtained with continuous fruit conveying and careful bin filling. The fruit conveying principle developed during 1965-66 was applied to a bin filler design. The stationary filler feeds fruit into a rotating bin thus minimizing fruit bruising by reducing the velocity differential between fruit entering the bin and fruit already in the bin. Another method of conveying fruit around corners was designed and is being applied to the positive-flow conveyor principle. For use in tree wall plantings a four-picker self-propelled multi-platform prototype harvesting unit was designed and is being constructed. Each fruit is separately conveyed from the picker's hand to the stationary fruit distributor within the rotating bin. It is hoped that this unit will increase worker productivity by 40-50 percent. Also for tree wall plantings an experimental harvesting unit consisting of three horizontal banks of closely spaced metal bars (6 feet in length) were constructed and tried. In theory, the units would be pushed into the tree from each side of the row and the apples separated from the tree by a shaker. The apples would fall (never more than a foot) onto the rods which would slope enough to carry the fruit to the outside of the tree. The tests brought to light some problems. However, the principle seems to warrant further investigation.

3. Harvesting Apples for Processing Outlets. Over 40 percent of the apples produced in the United States are processed. The critical shortage of harvest labor and the relatively low value of this fruit makes it imperative that harvest efficiency be increased. A commercial cherry harvesting machine was modified by adding decelerator strips, curtains, and flights to the conveyor. It was used in harvesting more than 12,000 bushels of Jonathan apples. The three-man crew averaged 125 bushels per hour. Five different companies processed the apples and the results showed the quality was satisfactory. A prototype kit for converting cherry harvesting equipment for use in harvesting apples will be developed and tested in FY 67. A leaf and spur removal unit was developed and proved to be very effective--so much in fact that one processor already has installed one in his packing line. An experimental roll-out type catching frame with decelerator strips was constructed and used in harvesting over 1100 bushels of McIntosh and Jonathan

apples. Results were so promising that a prototype unit will be constructed and tested for 1967 season. It is hoped that it will have a capacity of 200 bushels per hour with a three-man crew and a cost of under \$10,000. A pick-up unit consisting of a metal drum studded with thin nail-like spikes was constructed and used in picking up several hundred bushels of apples. It had a high capacity and picked up over 99 percent of the apples. However, processors are afraid that dirt may get into the one hole which is made in each apple. Another type of pick up consisting of a metal drum with rubber flails which sweeps the apples onto a fixed bed plate was constructed and tested. Although it picked up the fruit, its capacity was low and it picked up considerable amounts of trash. Several other pick up principles have been tested in the laboratory and one principle--that of padded discs--looks promising and a field unit will be constructed and tested next season.

4. Harvesting Blueberries. Practically all the Michigan cultivated blueberry crop and a high percentage of the crop in other states was harvested mechanically by methods developed on this project. Last year, 21 large-capacity continuous harvesters costing \$30,000 each were used. Ten more machines costing \$30,000 and 20 more costing \$35,000 have been purchased for FY 67. Labor requirements for harvest have already been reduced by more than 15,000 workers and harvest costs lowered from 8 cents per pound to under 4 cents per pound. The objective of this research has been achieved and this project was terminated this fiscal year.

5. Harvesting Tart Cherries: Last year 28 percent of the Michigan crop of red tart cherries and 22 percent of the national crop were harvested mechanically with equipment and methods developed by this project. It is important that fruit quality be maintained if mechanical harvesting is to benefit both the grower and the processor. A new experimental electronic sorter made by the Sortex Company was evaluated. The unit has a high capacity (5,000 lbs./hr.) and sorted the cherries effectively. Michigan processors have purchased 25 units for next season. Seven destemmers, which unit project personnel helped design, were used commercially and evaluated. The destemmers had a rate of 8,000 lbs./hr. and removed about 99 percent of the stems without bruising the cherries. Several changes in design were recommended and these will be incorporated in the 30 new units being manufactured for 1967. A study of thermal properties was completed and the results made available. Further studies with the PL firmness meter developed on this project showed it to be a satisfactory method for measuring firmness. A study of bruise level and firmness showed that product yield was inversely proportional to bruise level. A study of soak water temperatures showed that there was no advantages in using 39° F. water instead of the conventional 56° F. soak water. In fact, at 39° F. firming was slower and product yield slightly lower. The effect of temperatures of the fruit as harvest on firmness, quality, and product yield were made. Results show a definite correlation between harvest temperature--the cooler the fruit the better the yield. An effort to cool fruit on the trees was made by spraying the tree and fruit with 58° F. water from an air blast sprayer. Results show that a two-minute spray cooled the fruit as much as 18° F. This method looks promising and further studies will be made.

6. Harvesting Clingstone Peaches. Although principles for mechanical harvesting clingstone peaches were developed on this project several years ago, no one has made prototype equipment. The harvesting labor supply has become serious. The major effort for this project during 1966 was in the design, construction, and testing of a cling peach harvester. The primary objectives of the program initiated were to (a) to design and test a harvester using previously developed principles considered essential for cling peaches, (b) to determine the influence of tree modification as a means of improving fruit recovery and reducing fruit injury, and (c) to determine the ability of modified trees to recover yield loss as a direct result of modification. A shake-catch harvester with several new design features was constructed, and field tested. The harvester consists of two units, one for each side of the tree, with a shaker on each unit. The machine also includes a sizer for removing small fruit, a bin filler to minimize injury to the fruit going into the bin, a blower for removing leaves, fabric catching surfaces on which dampen fruit bounce, and a maze of parallel sponge rubber tubes to decelerate fruits and minimize fruit-on-fruit impact when falling on and near the conveyor. Equipment performance was considered good although some changes are thought advisable. The concept of a man and shaker on a tractor worked well and increased harvest rate. It permitted one person to operate the shaker and move the frame. Having a shaker on each side proved desirable. Devices used for decelerating, padding, and catching fruit were effective in preventing fruit damage. Fruit drainage from the catching surfaces needs to be improved as do the hydraulic controls for power to the axles. More flotation is also necessary on loose ground. The sizer and bin filler both need some modification but were generally satisfactory. The conveyor which was a wide low-speed unit caused no damage to the fruit. The arrangement for hand sorting defective fruit on the sizer needs further study. Harvest rate was greatly affected by the training of trees. On good trees average harvest rates of approximately 30 trees per hour were achieved. A three-to five-year study was initiated on the three tree training systems now in commercial use to determine the effect on yield, fruit damage and fruit removal. The degree of modification required to enhance the potential for mechanical harvesting is also being studied. Trees trained under one system required extensive modification involving removal of numerous major branches, whereas trees under another training system required only minor modification. Major modification resulted in considerable loss of bearing surface, but fortunately a low percentage of orchards are in this group. Hand- and machine-picked fruits were not significantly different at the orchard or cannery levels. Recovery of marketable fruit with machine harvest was within 2 to 6 percent of that with hand harvest.

7. Harvesting Pears. Many growers are planting pear trees in hedgerows. A multilevel picking platform was designed and constructed in order to test its feasibility in increasing harvesting efficiency. The multilevel unit is essentially a stairway on each side of a central conveyor; the steps being 2 x 2 feet and having a 1-foot rise from step to step. Five to six men can work on the machine. Limited tests of pruning and harvesting in hedgerows 6 feet wide indicate that the unit has potential for both operations.

8. Harvesting Sweet Cherries. In Michigan, the harvesting of the tart cherry crop is mechanized and workers are not now available for harvesting sweet cherries. In California and the Northwest labor is in short supply and mechanical harvesting methods are needed. In California a shaker was developed for use on olives and sweet cherries. This unit has a greater horsepower and stroke capacity than previous equipment and will be tested next season. In Michigan, about 150 tons of sweet cherries were harvested with tart cherry equipment and problems such as trash and fruit recovery were noted. The effect of time after harvest of bruising will allow the use of bruised fruit and still result in excellent quality.

9. Rheological Properties of Wood. Mechanical harvesting is being developed for most tree fruits. Vibration and other properties of fruit tree wood and bark are useful in designing shakers and other fruit detachment devices. Trees are also being shaped and trained to fit the equipment and the forces required to bend and train limbs are needed. Elasticity and damping characteristics of wood and bark were studied. A computer solution for the slow bending test was developed and published. Equations for determining dynamic and static properties using the above computer solution were derived. A tensile testing machine system in conjunction with a precision controlled temperature chamber is being constructed. The elastic modulus and the amount of internal damping in fresh Montmorency cherry bark and wood were determined. Both these properties can be used to predict the force and power to shake the tree limb as well as how far it will move. Bark sections were examined and photographed under a microscope and studies of tensile strength were made in longitudinal and tangential directions. Cambium shear strength also was measured. These values are of use in designing shaking equipment.

D. Forage Seed Harvesting Equipment

1. Development of Components for Cutting, Picking up, Threshing, and Cleaning Field Seed Crops. Rotary cutter tests were continued in 1966 to develop a new method of picking up seed crops for an improved-type combine. A commercial rotary cutter was completely remodeled to increase efficiency of seed pickup and again tested in several grass and legume crops. Total seed picked up was 95.4 percent for windrowed red clover, 87.0 percent for standing red clover, 85.4 percent for windrowed creeping red fescue, 90.7 percent for windrowed Newport bluegrass, and 76.0 percent for windrowed perennial ryegrass. The best seed pickup condition was at a minimum cutter height of 0 inches but much undesirable additional material such as leaves, stems, and soil was also collected. The rotary cutter picked up a seed crop efficiently over a wide range of crop maturities but the normal combine seed pickup was greater than that for the rotary cutter when the crop was mowed at the recommended time according to standing seed moisture. No further improvements are planned. The decision whether or not to use the cutter as a component part of an improved combine will be made after other components are developed and tested.

Time-of-harvest studies have been or are being conducted on nine grass and legume crops. A new method of summarizing and showing the data for each crop on a single chart has been devised. The single chart shows an average seed moisture dry-down curve and an average pure-live-seed harvested curve as well as indicating the seed moisture and moisture drop per day at optimum mowing time.

Time-of-harvest studies were continued on bluegrass in 1966 to determine the optimum mowing time as indicated by pure-live-seed yield. The 1966 test was the fourth year for Merion and the third for Newport bluegrass. The optimum mowing time for Merion was at a seed moisture of 35 percent and for Newport--19 percent. The optimum times in 1966 were indicated by well-defined peaks on the pure-live-seed harvested curves as compared to relatively flat curves for previous tests. The data gathered on bluegrass in five years of tests was judged adequate; therefore, time-of-harvest study with bluegrass will be discontinued.

Time-of-harvest studies were continued on fineleaf fescue in 1966, for a second year, to determine the optimum mowing time as indicated by pure-live-seed yield. Both creeping red and Chewings varieties were tested. The optimum mowing time for creeping red fescue was at a seed moisture of 23 percent and for Chewings--28 percent. The optimum times in 1966 were again indicated by well-defined peaks on the pure-live-seed harvested curves. As in 1965, this harvest was five days for creeping red and six days for Chewings after the farmers mowed in the same field. Time-of-harvest studies with fineleaf fescues will continue another year to gain the usual three year sequence.

Time-of-harvest studies were started on perennial ryegrass in 1966 to determine the optimum mowing time as indicated by pure-live-seed yield. The optimum mowing time for perennial ryegrass was at a seed moisture of 40 percent. The optimum time to mow precedes the time when total seed produced is a maximum because of high shatter losses. Since the optimum time of harvest was near the first cutting time, the study will continue at least another year to obtain data on the "up" side of the pure-live-seed harvested curve.

E. Oilseeds and Peanut Harvesting Equipment

1. Studies to determine the effect of pruning and training tung trees for mechanical harvesting showed that trees growing to a natural crown had significantly more growth than those trained to a 5 1/2-foot crown. In the pruning treatment, there was very little difference in the amount of growth put on by the different treatments. No fruit was produced in the training experiment in 1966 due to cold weather at blooming time.

2. Development of an experimental tung nut harvester has continued. Additional cleaning features have been added to improve the performance. Using the basic principles of this unit, 13 harvesters were built commercially in

1966. All of these were used during the harvest season. These harvesters worked fairly well; however, they were too lightly constructed and trouble with conveying and cleaning mechanisms was experienced.

3. A study of peanut digger performance in Virginia showed that commercially available diggers left as much as 23 percent of the crop in the ground and an average of 25,000 pounds of soil per acre left mixed with the vine mass. An experimental digger equipped with either a standard conveyor and an elliptical wheel dirt-removing assembly or with two conveyors, left an average of 14 percent of the crop in the ground and an average of 14,000 pounds of soil per acre mixed with the vine mass.

Tests of the effect of inverting peanut windrows showed that peanuts from inverted windrows dried significantly faster than those from the random windrow which were in contact with the soil. Samples of these peanuts were taken over a 14-day period and analyzed for aflatoxin. No traces of aflatoxin were found.

4. Peanut harvesting loss and damage studies conducted in Virginia showed that the visible pod damage ranged from 14 to 37 percent. Total pod damage (both visible and invisible) ranged from 42 to 67 percent. Preliminary studies indicate that the combining damage can be reduced by operating the cylinders at slower speeds. Losses were also less at the slower cylinder speeds; however, all losses were rather low, ranging from 3.9 to 5.5 percent. Studies to determine the combine efficiency as affected by soil incorporated with the vines showed that neither pod damage nor recovery yield was affected by soil in the vine mass.

Investigations with an experimental recleaner to clean combine-run peanuts prior to drying showed that approximately 50 percent of the immatures could be removed from green combined peanuts which had 22 percent immatures. Following one- to seven-days exposure in the windrow before combining, the recleaner removed approximately two-thirds of the immatures which averaged about 17.5 percent of the total.

Investigations of the effect of type of windrow on drying rate and flavor of peanuts indicated that peanuts from inverted windrows, under Georgia conditions, dried only slightly faster during good drying weather. Under unfavorable drying conditions, the peanuts in the inverted windrow appeared to dry much faster than those in the normal or random windrow. A statistical analysis of the taste panel evaluations is not available, however, there do not appear to be any striking differences either as to type of windrow or exposure time in the windrow. Studies on peanut kernel temperatures reached within the windrow showed that all peanuts, regardless of position, may reach temperatures far above those recommended for drying with heated air. The highest temperatures were found to be in peanuts which were both in contact with the soil and exposed to the sun. These temperatures, measured in excess of 120° F., were approximately the same as those of the soil surface and of a black globe six inches above the ground. Studies also

failed to detect the development of aflatoxin in the windrow in either random windrows or inverted windrows for this season. These studies included Spanish, Runner, and Virginia types which were left in the windrow either 0, 3, or 7 days. In none of these treatments was aflatoxin found in peanuts taken from the combine. The effect of clipping peanut vines, prior to digging, on drying rate indicated that there was no advantage in this operation. Approximately one-half of the top was clipped immediately prior to digging. When the peanuts were windrowed in the normal, random windrow or in an inverted windrow, the drying rate was about the same for these as for those from which the tops were not clipped. Studies to determine the effect of windrow type and exposure time on broken and damaged pods indicated that the percentage of peanuts coming from the combine is about the same regardless of these factors. The percent of damaged hulls prior to combining increased with exposure time; however, the peanuts which were in the windrow longer were less damaged by the combining operation. As a result, the total damage was about the same.

5. Under research contract at the Georgia Agricultural Experiment Station at Tifton, studies to determine the nature and extent of losses during the harvesting operations showed that, for this year, total losses were very low. The Virginia-type had a higher percentage loss for both digging and combining. The combining losses were higher than the digging losses for the Spanish type. The two types of losses were about the same for the Runners, whereas most of the total losses for the Virginia-type occurred in the digging operation. Studies to determine the effect of clipping peanut tops on pod losses indicate that the percentage of vine growth removed had little effect on recovery yield. In all instances at least two inches of vertical growth was left. A sharp, sickle-type mower was used for these studies. The amount of forage (dry matter) recovered per acre ranged from 700 pounds per acre for the Spanish to 1400 pounds per acre for the Virginia-type. Average protein content of the forage was 12.4 percent, 12.8 percent and 14.8 percent for the Spanish, Virginia, and Runner types, respectively. Tests to determine the nature and extent of digging losses showed that these losses did not increase appreciably up to the normal maturity date. Radioactive phosphorous was applied to the plants prior to digging and those recovered from the soil were put on x-ray film to determine whether the peanuts were actually connected at the time the phosphorous was applied. The analysis of this data has not been completed. Studies to determine the location within the combine at which the most damage occurs indicate that the first two picking cylinders contribute very heavily to the damage. Peanuts were collected from the windrow and nine locations in the combine. Peanuts collected after the first three picking cylinders generally had a majority of the total damage. Indications are that the point at which the most damage occurs is influenced by the moisture content of the peanuts. As the moisture content decreases, less damage appears to occur at these cylinders and more appears to be contributed by the remaining components, with no appreciable difference in the total damage.

F. Potato Harvesting Equipment

1. Multirow Harvesting of Potatoes. Potato harvesters are expensive and anything that can be done to increase their efficiency or use is desirable. Multirow harvesting methods are now being used by some growers. A comprehensive engineering analysis of multirow potato harvesting methods was made and a manuscript has been prepared for publication. This should provide a guide for potato growers in evaluating the potential merit of four-row indirect harvesting operations with specific combinations of yield, annual acreages, and labor requirements.
2. Bruising of Potatoes. Bruising continues to be a major problem in harvesting and handling potatoes. An instrument which growers could use to determine when potatoes were least susceptible to bruising would be of real value. Final testing of an impact instrument was completed and results show that it is an excellent instrument for measuring susceptibility to bruising. A publication is being prepared on the design and use of this instrument.
3. Dust Applicator for Seed Potatoes. Although dusting potato seed pieces has many advantages, no commercial equipment for uniform application insuring complete coverage of the surface is available. Grower-made equipment does not contain the dust to avoid air contamination in the work area. The experimental applicator described in last year's report was used under commercial conditions in treating about 3500 cwt. of seed potatoes. Two manufacturers have since made units.

G. Sugarcane Harvesting Equipment

1. Auger-Type Pickup and Chopping System for Harvesting Recumbent-Type Sugarcane. A pickup system, incorporating two horizontal augers picking up and feeding the cane, was designed and field tested. The 20-inch outside diameter augers with 12-inch tube and 12-inch pitch pushed the cane to one side, picked it up with fingers mounted on the core, parted the cane from the adjacent row with a circular disk, fed the cane between the augers, and chopped it into short lengths with the mating flights. The throat area of 7 inches x 6 feet between the augers turning at 100 r.p.m. was sufficient for a capacity of 1700 pounds per minute at operating speeds of 3.8 m.p.h. The auger speeds were increased to 133 r.p.m. and the apparent capacity was approximately 2300 pounds per minute at an operating speed of 5.75 m.p.h. The most serious problems with this system were (1) the need for location of the auger directly on the bottom cutter, and (2) the need for the discharge conveyor to be the same width as the augers. High-speed movies of the auger cutting action and discharge show that a nice clean cut is being made on the cane pieces. Some cane is fed through without being cut into short pieces when the flow of cane is light. The discharge of cane at the rear of the augers should not be any problem when a platform or conveyor is arranged to take it away as it flows. Further work will be done on an oriented finger to work in conjunction with the lower auger and with a solid platform behind the augers.

Evaluation of bottom cutters. As a continuation of the work last year, five additional types of bottom cutters at various speeds were evaluated through the use of high-speed photography. A 37-inch diameter rock blade and a 42-inch diameter cutter with rectangular segments, both installed on a Toft Australian harvester, were evaluated. These two cutters were travelling at speeds of 900-2400 f.p.m. These speeds did a poor job in recumbent cane in Florida, since the canes were not held in the rubber carrier chains while being cut as in erect cane. The double 26-inch notched circular cutters with augers were evaluated again after the manufacturer changed the blade as a result of the previous years' work. The removable sections with large notches and hard-surfaced edge did a much better job of cutting at ground level. The stalks were sheared without being pushed forward as was done previously. The double 24-inch bottom cutters, designed on the project, were evaluated with two types of sections at speeds of 5000-11,000 f.p.m. The heavy duty section with a 3/4-inch nose width did a better job of cutting than the 2-inch width section. At 11,000 f.p.m. with the 2-inch nose width, a considerable amount of chips or pulp was knocked from the cane stalk as it was being cut. It was evident that this range of speed was faster than necessary for cutting sugarcane stubble. The tip speed of between 5000 and 6000 f.p.m. was recommended. The action of the bottom cutters was good as observed through the aid of high-speed movies. By turning both cutters inward, the cane was sheared together and the stubble remained more intact than with other types of cutters. The forward tilt of the cutters had to be increased to approximately 5° with the horizontal in order to decrease mutilation of the cane stubble.

Cleaning sugarcane on the conveyor. The experimental auger harvester cuts the cane into short pieces as it is being harvested and deposits it on a conveyor. Some leaf and dirt trash is separated from the cane by the augers and gathering fingers. An open mesh conveyor bottom removes soil and some small trash. One section of the conveyor has notched-tooth cleaners which are timed to operate through the conveyor slats, snagging leaves and tops which are pulled down through T-slots and discharged onto the ground. These cleaners have not proved to be aggressive enough to do effective cleaning. Additional speed on the notched fingers would improve cleaning, but to do this the timed conveyor slats would have to operate at an excessive speed.

Spiral roll cleaning and conveying. Two pairs of spiral rolls 68 inches long, of the kind used in sugar beet harvesters, were tried for cleaning and conveying sugarcane. These are made from 5-inch pipe wrapped with 5-inch pitch spirals of 5/8-inch rod. Several arrangements of rod and rolls were used. A final arrangement with the rods machined to a flat surface gave good cleaning and conveying up to 10°. At greater inclines, it would be necessary to hold the cane against the spirals. Rotations of 500-600 r.p.m. were used with the rolls mounted on the auger harvester to receive the discharge of the conveyor and to cross-convey the cane to a cane cart and to provide additional cleaning. Several other cleaning devices have been constructed and are being studied, including octagonal plate rolls, beaters, and flails. These could act as devices for loosening trash and dirt, holding cane against other cleaning equipment, and in moving the cane along the conveyor.

A reel-type cutting system. A system of harvesting cane using a large diameter horizontal reel was designed and field tested. This system was designed to cut into the cane from the top down and chop the cane into small pieces as it was cut loose at the ground. The reel was 4-feet wide and was 6 feet 6 inches in diameter to accommodate the tall canes. Reel tip speeds of 3400-8400 f.p.m. were tried with ground speeds of 1 and 3.8 m.p.h. The system was mounted on a harvester frame for field testing and was powered by an auxiliary engine. The results of the field tests indicate that the large reel will cut and chop cane with very little stoppages in the field. However, the resultant chopped material was not satisfactory as it contained approximately 30 percent trash. Observations of the cutting blade using high-speed photography indicated that the stalk being left by the cutting blade was sheared cleanly, but the piece chopped off and accelerated was being shattered by the blade. Two other modifications of the blades to eliminate the support which seemed to cause the shattering did not correct this sufficiently. Approximately 30 hp. was used to power the reel cutting one row of cane at a rate of approximately 1000 pounds per minute.

2. Mechanically Removing Tops and Leaf Trash from Sugarcane. During the 1966 harvest season in Louisiana, experimental sugarcane cleaners employing flat picking belts, a notched-tooth drum and brush arrangement, sets of square cleaning rolls, and sets of hexagonal cleaning rolls, were tested under a research contract with Louisiana State University. Each cleaning unit was designed in an effort to detach the tops and leaf trash which was not detached by chopping the mature stalks into short lengths. The picking belts removed from 30-40 percent of the total trash and from 55-75 percent of the loose trash. These removed few immature tops. The notched-tooth drum and brush cleaner removed approximately 58 percent of the total trash but lost a considerable amount of mature cane. The cleaning rolls were the most effective method of removing trash and both gave better results when positioned parallel to the flow of cane. The cleaning rolls removed from 50-75 percent of the total trash with the square rolls being the most aggressive and snapping more of the tops. Rubbing rolls were not effective in detaching trash from cane and an air blast did not improve the operation of any of the rolls. More work will be done with the cleaning rolls and notched-tooth drum and brush cleaner to improve effectiveness. When the same cleaners were operated in Florida, results were generally better. The square rolls removed up to 85 percent of the trash from mechanically harvested and topped cane. Snapping of immature tops was more difficult. Alternating pairs of rubber and steel corn husking rolls were very aggressive but did not prove as successful as the square rolls. Round rolls seemed to offer little advantage in cleaning.

H. Tobacco Harvesting Equipment

1. Research was continued on the handling of stalk-cut tobacco on portable curing frames utilizing fork-lift techniques. An "on-the-farm" assembled steel portable curing frame has been developed. A sled having hydraulic-powered ejection of the filled frame was used to reduce labor required to place harvested tobacco into the frames. Four curing methods were used,

(1) curing without supplemental heat in an air-cure barn, (2) curing with oil-fired automatically controlled heat in an air-cure barn, (3) curing with propane-fired automatically controlled heat in a forced-air ventilated barn, and (4) air-curing within temporary plastic enclosure attached to the portable curing frames. Experimental handling procedures involving forced-air required excessive fork-lift operator skill to accurately position the frames in the barn. Cured "out-of-case" tobacco was satisfactorily removed from the barn while in the frames, then placed into a plastic enclosure to be cased for market preparation using an evaporator heated by an automatically controlled burner. Labor required for field handling, transport between field to barn, housing, removal of cured tobacco from the barn, and casing with steam was 35 to 40 man-hours per acre. Mean value of tobacco air-cured without supplemental heat was 61 cents and 64 cents per pound when stick spacing was 5 and 6 inches, respectively. However, when supplemental heat was applied, the values of cured tobacco was 64 cents, regardless of stick interval. The use of steam to permit market preparation, regardless of weather conditions, had no significant effect upon the quality of the tobacco as indicated by government grade. During 1967 the handling system involving air-curing will be tested at farms of grower cooperators.

The objective of handling stalk-cut air-cured tobacco on vertically suspended strings is to design a harvest-housing system having efficient use of men and equipment. A system is proposed utilizing a tobacco harvester having the function to fasten the base of stalk-cut tobacco to continuous twine. "Chains" of stalks will hang from a rail system constructed near the top of an air-cure barn. Control and power circuits for hydraulic or hydraulic and pneumatic harvester components have been designed. Curing tests have indicated satisfactory air-cure using the proposed procedure of handling.

I. Corn Harvesting Equipment

1. Research was continued on the causes and effect of mechanical damage to field-shelled corn during harvesting and handling. A study of sampling methods for assaying damage done during shelling showed that manual examination, even with fast green dye, is subject to wide errors in results. Because manual examination does not dissolve the real damage done by a shelling machine, two new promising assay methods are under development. A mechanism for shelling by squeezing and rolling rather than by impact and abrasion is being tested. It operates fairly well on corn that has been held on the ear for several months, and will be ready to try on fresh-harvested corn during the fall. It is hoped that corn shelled in this way will be as sound as hand-shelled corn. Measurement of the forces required to detach the kernel, to fracture the seed coat, to deform the kernel, and to rupture the cob, indicate that the impact and abrasion typical of current shellers are not essential to separation of the kernels from the cob. They are, however, responsible for a large part of the kernel damage.

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AREA 5: CROP PREPARATION AND FARM PROCESSING (EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, and to preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently, this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA AND COOPERATIVE PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers, and farmers. Forage processing is under study at Tifton, Georgia, in cooperation with the Coastal Plain Experiment Station. Manufacturers cooperate through loan of equipment. Research on the processing of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Mississippi Experiment Station and industry. Farm curing and drying of peanuts is cooperative with the Virginia and Georgia Experiment Stations.

The Federal engineering effort devoted to research in this area totals 8.5 scientific man-years. Of this number, 2.5 are devoted to seed cleaning, 1.0 to curing tobacco, 2.0 to drying of grain, 1.2 to forage processing, 0.2 to tung nut processing, and 1.6 to peanut curing.

PROGRAM OF STATE EXPERIMENT STATIONS

Many freshly harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The state agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives

the development of improved methods, equipment, and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The scope of the current program may be best illustrated by describing it in broad areas of study.

Drying or curing investigations are in progress on forage crops, cereal crops including rice, feed grains including grain sorghums and soybeans, nuts, tobacco, peanuts, and coffee. Farm processing studies are under way for forage wafering and hay storage; precooling of freshly harvested crops such as citrus, sweet corn, and vegetables; pre- and poststorage treatment of potatoes; dehydration and mechanical dewatering of crops; seed and grain cleaning and separation; and trimming, peeling, and juicing operations for crop marketing.

Closely associated with these studies are development and adaptation studies of flow systems, equipment, and packages to move products without damage into and out of storages and to the market place.

Much of this research is cooperative with the Department.

A total of 35.6 scientific man-years of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cleaning

1. Seed cleaning research was conducted in the attempt to improve on existing techniques for processing given seed mixtures, either by performing more precise separations with conventional equipment or by developing and using new equipment to exploit seed differences more effectively. Proper screen selection for dimensional separations was studied through measurements of seeds and screen openings. An analysis of seed dimensions (length, width, and thickness) indicated whether a screen separation was feasible, what the optimum shape and size of screen openings for making the separation should be, and the yield and purity of the final product that could be expected when a given screen was used. Experimental verification trials made with measurement-dictated screens showed a good correlation between theory and practice in many cases, but poor correlation in others. The poor correlation was attributed mainly to sampling error, seed shape effects, and inaccurate screen holes. Seed measurements have been accumulated for many different seed types including bluegrass, bentgrass, alfalfa, cotton, fine fescue, ryegrass, timothy, corn, and others, as well as frequent contaminants found in these crop seeds. Measurements of screen openings showed many inconsistent hole sizes due to wear, dislodged wires, or manufacturing methods.

Several aspects of screening were investigated with regard to accuracy of separation. It was found that dams on screen improved separations because they interrupted the seed flow across screens, provided many orientations of seeds with respect to screen openings, and encouraged hesitant seeds to drop through the screens if dimensions permitted. This increased the accuracy in sizing or separating of seeds, and reduced seed loss. Duration of the screening process also was found important with regard to providing enough time for all potential "droppers" to find a hole and/or the necessary seed orientation for dropping. Considering the seeds capable of passing through a given screen, one minute exposure was required for 90 percent of these seeds to drop, and additional seeds were still dropping two minutes later. A comparison of hand screening and machine screening (using dams) showed that the two operations were very similar in terms of splitting the lot and dropping seeds of the same size when a long screen exposure was employed. Another screening study was conducted to establish the correlation between round and square holes that do equivalent screening jobs. Working with seed types of various shape, cross section, and size, it was found that the ratios of square holes (side dimensions) to round holes (diameters) for equivalent screening varied with the seed type and the amount of split considered for any one seed type. In general, the screening action of a given round hole was duplicated by a square hole whose side dimension was approximately 80 percent of the round-hole diameter.

Experimental equipment was developed in several instances where conventional separators could not do the required job. A catapult was devised to propel seeds through still air and take advantage of different trajectories that seeds would follow according to the resistance they encountered in flight. Tests showed some tendency for seed trajectories to differ, but results were inconsistent and good separations could not be made. A resilience separator has been constructed to investigate elastic behavior of seeds--another new, potentially useful separating basis. Several models have been built with the basic arrangement--that of dropping seeds on inclined plates and catching seed fractions at various distances from the plates. Trajectories in this development are influenced by the seed resilience. A present model with multiple glass plates has shown encouraging results in bouncing ryegrass out of orchard grass, asparagus from beets, and dirt clods from white clover.

Testing programs have been conducted with three types of conventional seed separators. The magnetic machine separates components of a seed mixture according to their surface textures and how well they pick up iron powder. This unit was tested to learn how separation efficiency was influenced by moistening liquid, type of iron powder, and additives like soluble oil or wetting agents. It was found that increased moisture (up to about one-third pound of water per bushel of seed) improved the removal of dodder and buck-horn plantain from red clover. Type of liquid was relatively unimportant, but type of iron powder was very important--the finer the powder, the better. A color sorter, that classifies material according to color or light-dark characteristics, was tested to learn its potential in separating small seeds. So far, acceptable results have been obtained in processing

onion, rice, mustard, safflower, and barley. Several classes of pneumatic separators were evaluated. These machines, which separate products according to terminal velocities, were examined at two velocity ranges. The test results made it possible to rate various machines in over-all selectivity; batch separators sealed against air leakage were found more selective (as a group) than continuous flow units. Generally, the selectivity of a given separator tended to decrease as terminal velocity of the handled product increased.

2. Three types of commercial pneumatic vibrators were tested to determine their suitability for use on feeders for seed or grain. The primary consideration was delivery of a uniform flow of grain at a given setting. None of the three vibrators appeared to be well suited to the desired requirements for a feeder due to poor frequency control which governed feed rate, excessive use of air, or narrow range of controlled feed rate. Therefore, other designs will be tested. The next step in this study will be to build and test a mechanical feeder driven by a synchronous motor with the expectation that the precise control of motor and vibrator frequency will make possible a uniform feed rate.

B. Tobacco Curing

1. Curing burley tobacco under modified environmental conditions. Fan ventilation of regular tobacco barns was continued. Most of the conclusions reached in previous studies were further verified with one major exception. Supplementary heat units can and should be capable of creating more than a 10° to 12° F. temperature rise in the barn. This is especially necessary during cool damp curing periods as those experienced in 1966. However, during the early stages of the cure special care must be taken not to over use the extra heating capacity to the point of drying the tobacco too fast and setting green color in the leaf. Another problem with forced ventilation systems is lack of uniform density of the tobacco. Extra care must be taken during loading operations to assure uniform tobacco density along each rail and from one rail to another. Improved air distribution from the fan needs further study.

Curing primed burley tobacco. The objective was to compare two curing methods --primed-leaf curing and stalk-cut curing--on the basis of leaf-drying rates and physical and chemical characteristics of the leaf. This was a continuation of 1965 research. Leaves were primed at five biweekly intervals during the season. Based on standard grade analyses of the cured tobacco, the treatments were judged in order of preference as follows: (1) Stalk-cut, cured at constant conditions of 90° F., 70 percent r.h.; (2) primed-leaf, cured at 90° F., 80 percent r.h.; (3) primed-leaf, cured naturally; (4) primed-leaf, cured at 90° F., 60 percent r.h.; and (5) stalk-cut, cured naturally. Chemical analysis showed that a rapid decrease in protein nitrogen content of the leaf during the first three days of the cure was desirable. Samples for which the protein nitrogen decreased about 30 percent during the first three days and about 40 percent during the first six days were judged

less desirable than samples for which protein nitrogen decreased about 40 percent in three days and 45 percent in six days. This compares with the expected decrease in protein nitrogen of 50 percent during normal curing. A comparison of chemical analyses at various leaf moisture contents indicated that chemical changes in leaf laminae were arrested at about 200 percent moisture content dry basis.

These results show that environmental control can be employed to manipulate desired physical and chemical changes in both primed and unprimed leaves.

Mass and energy balance of burley tobacco during the cure. The objective of this investigations is to obtain data for the design of controlled or modified environment curing structures for burley tobacco. This design will require knowledge of the basic properties of tobacco under various curing conditions. The major ventilation load of an air-cure system is the heat and moisture evaporated from the tobacco. Investigations indicated that 30 to 60 percent of the heat required to vaporize this water from the curing tobacco plant might be available as heat produced by respiration. The lack of information reported in the literature and the potential application for the knowledge of respiration heat and moisture removal to a curing system prompted this study. A respiration calorimeter has been designed and constructed for measuring the effect of temperature, humidity, and air-flow on the mass and energy exchange between the curing tobacco plant and its environment.

Portable colorimeter for tobacco leaves. An instrument was sought which would be fast, portable, and inexpensive but would still give satisfactory results in evaluating the colorimetric properties of tobacco leaves. The principle of operation involves analysis of reflected light from the leaf sample. The reflected light passes through a colored filter to a selenium photocell. Light striking the photocell surface causes electrons to flow. This current is a measure of the intensity of light. Instrument data were converted to a standard color language system. The color system recommended by the 1931 International Commission on Illumination (ICI) was used. The proposed objectives of portability, speed, and low cost were met. The results, however, showed an error of ± 10 percent in the ICI color coordinates when compared to a Spectronic 505 spectrophotometer. This is not good enough for separating tobacco into exact grades; however, meaningful results could be obtained when comparing leaves, or in detecting changes in colorimetric properties during growth or curing.

C. Grain Drying

1. The time limitation on storing grain under any given condition is dictated by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of

these factors on the rate of growth of the microflora and subsequently the rate of deterioration. Continued study of carbon dioxide production in shelled corn samples verifies the damage done by field shellers. Tests started very soon after picking and shelling indicate that there may be a short period of fast respiration immediately after picking, for both damaged and undamaged kernels; and that during this short period there is little difference in activity between damaged and undamaged kernels. Aflatoxin showed up in substantially all the samples that were held long enough at temperatures of 75° F. or higher and 23 percent moisture or higher. It is not clear just how long an exposure to these conditions is required for development of measurable aflatoxin.

D. Forage Processing

1. One year's results of the effect of irrigation of Coastal bermudagrass on processing indicate that there is no effect of irrigation on the unit processes. Although the irrigated grass appeared to have a higher yield for the season, the difference was not significant. The irrigated plots produced significantly more grass the first cutting and the non-irrigated plots produced significantly more the second cutting. For the next six cuttings, there was no significant difference. The analyses of plant constituents are not yet available. These studies will be continued.

Studies to determine the effect on processing energy for wilted millet showed that wilting for 1, 2, or 4 hours reduced the energy requirements compared to direct-cut material. The largest reduction in energy occurred in the fuel required to dehydrate. Even with wilting 4 hours, about 20 percent more fuel was required to dry the millet than to direct-cut and dehydrate Coastal bermudagrass. The analyses of carotene and other constituents for these treatments are not yet available. An empirical equation to calculate the fuel required to dehydrate millet ranging from 60 to 90 percent moisture (w.b.) has been derived.

Studies of the effect of additives on pelleting energy requirements for Coastal bermudagrass showed that cottonseed meal, cottonseed meal and ground corn, or cottonseed meal and animal fat all reduced the pelleting requirements for partially field-cured Coastal bermudagrass hay. A mixture of 10 percent cottonseed meal plus 4 percent animal fat reduced the energy requirement by about 45 percent, or about the same as for pelleting 4-week-old dehydrated hay. The addition of molasses increased the energy required when the same die was used. When the same material was pelleted through a thinner die, the energy required was only about 80 percent of that required by the check. The pellet density and durability were comparable.

A commercial, field-going hay cubing machine was evaluated as a stationary unit for Coastal bermudagrass. These tests indicated that the amount of moisture is more critical for this process than for pelleting. It appears that with a uniform feeding mechanism to allow the water added to be carefully controlled, and either a slightly longer die or one with a slight taper, the machine will produce Coastal bermudagrass cubes.

2. Preparation for evaluating the effect of processing treatments on the digestibility of Coastal bermudagrass has been made. Equipment for studying the effect of treatments on the breakdown of the lignin within the cell wall has been obtained and a technician is being trained to prepare and evaluate slides of forage from different treatments.

E. Tung Nut Processing

1. Preliminary tests on-the-farm drying of tung nuts were conducted using whole fruit. These tests indicated that the moisture content of 5 tons of fruit could be reduced from 41 percent to 13 percent in 10 hours of continuous drying. Additional studies to determine proper air velocities, temperature, and drying time will be made.

F. Peanut Curing

1. Studies of the effect of different drying rates on aflatoxin development in peanuts under Virginia conditions showed no aflatoxin development in artificially cured peanuts. The time lapse between digging and the completion of drying ranged from 10 hours to 10 days. One sample of peanuts cured on a stack pole showed 4 p.p.b. of aflatoxin B₁.

Investigations to relate the curing time-temperature-moisture content to peanut quality factors indicate that short cycles of heated air and cooling air can increase the drying rate without decreasing peanut quality. Empirical equations are being developed to express this relationship.

2. Investigations were conducted to determine the development of aflatoxin in peanuts held between combining and drying under Georgia conditions. The three major types of peanuts were held for 24, 48, or 72 hours between combining and placing on the drier. These peanuts were aerated at 0, 0.1, 1.0, and 10 c.f.m. per cubic foot. No aflatoxin developed in those peanuts combined immediately behind the digger or those exposed for 3 days in the windrow. In those which were dried to 10-15 percent moisture content and then rained on, traces of aflatoxin were found following these holding treatments. Its development appeared to be unaffected either by aeration rate or holding time. Similar peanuts which were placed directly on the drier did not show any aflatoxin development.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA 6: COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed, and trash, packaging, and sampling to preserve the inherent qualities of the end products. Ginning is the final operation in cotton production since, subsequent to ginning, title to the lint and seed passes from the producer and the products enter the market channels.

Rapid methods of harvest have come into widespread use during the past twenty years placing heavy burdens on cotton ginning research. Although developments growing out of the USDA Ginning Research Program have been revolutionary, many problems are yet to be solved, some of which are growing acute. The need is increasing for further automation of the ginning processes to effect better quality control and reduced labor costs.

In quest for lower unit costs, mills are continually demanding more and more of cotton as they increase machine and processing speeds. At the same time the trend continues to demand cleaner and cleaner cotton. Thus with the farmer gathering more and more foreign matter with the cotton, the cotton trade demanding cleaner fiber for a given grade, and the manufacturer demanding more and more performance, the gin's role becomes most complex. More efficient cleaning equipment which will minimize fiber degradation at reduced labor and power costs and effective efficient methods of trash collection and disposal are among the more urgent needs.

USDA AND COOPERATIVE PROGRAM

The USDA has a continuing long-term program involving agricultural engineers, physicists, and cotton technologists engaged in basic and applied research on the engineering and quality phases of cotton ginning.

Gin performance and cotton quality, waste collection and disposal, and gin stand research are being conducted at Clemson, South Carolina; Mesilla Park, New Mexico; and Stoneville, Mississippi. Seed cotton handling and storage, seed cotton conditioning and conveying research are underway at Stoneville, Mississippi, and Mesilla Park, New Mexico, seed cotton cleaning studies are carried out at Clemson, South Carolina, and Stoneville, Mississippi. Lint cleaning and packaging tests are conducted at Stoneville, Mississippi.

The Federal engineering effort devoted to research in this area totals 15 scientific man-years. Of this number 0.9 is devoted to seed cotton handling and storage, 1.2 to seed cotton conditioning, 1.4 to seed cotton cleaning, 0.7 to conveying, 2.3 to gin stands, 4.9 to gin performance and cotton quality, 1.0 to lint cleaning, 0.4 to packaging, 0.0 to cottonseed, and 2.2 to waste collection and disposal.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State agricultural experiment stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques, and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 3.0 scientific man-years are devoted to this work.

PROGRESS - USDA AND COOPERATIVE PROGRAMS

A. Seed Cotton Handling and Storage

1. Work at Stoneville involved testing a specially designed side dump trailer and a receiving hopper. The receiving hopper is equipped with a vertically arranged feeder section, vacuum feeders, and hot air pickup. Refinements have been made based on last season's test and the unit is operational. It is estimated that the use of such a system will reduce gin labor cost as much as \$3.50 per hour and affect a savings of as much as 100 horsepower. Tests at Mesilla Park showed that commercial cotton handling valves when operating at 12-inches static pressure will leak air at a rate of 100 to 235 c.f.m. Modifications of design proved to reduce the leakage about 50 percent.

B. Seed Cotton Conditioning

1. Most of the efforts at Mesilla Park this year were directed toward controlling the Monoflow seed cotton conditioning system to obtain and maintain cotton at selected moisture levels. The results were satisfactory in that the treatment average lint slide moisture contents were plus or minus one-fourth percentage point of target value except for one treatment which was one-half point below the target value. Feeder foreign matter showed no significant differences due to adding moisture to the seed cotton. But, seed cotton cleaning machinery efficiency computed from trash weights collect-

before lint cleaning lint foreign matter measurements did show a significant difference between the driest treatment and the wettest treatment. Increasing the seed cotton moisture from 7.2 percent to 9.5 percent at the time of cleaning increased foreign matter content before lint cleaning from 5.1 to 6.8 percent. There were no significant differences in the lint foreign matter contents after lint cleaning. Fiber length before lint cleaning as measured by the Fibrograph (2.5 percent span length) was related to the feeder seed cotton moisture contents. Reduced moisture content at the feeder resulted in reduced fiber length.

At Stoneville an integrated automatic moisture control system was successfully demonstrated. Cotton of three distinct moisture levels was fed into the system. The system automatically routed wet cotton to appropriate driers and activated the moisture restoration subsystem when cotton entered the system too dry for adequate quality preservation.

The moving bed drier investigation showed that some agitation--tumbling or stirring--of a seedcotton mass during drying provides more rapid and more uniform drying than heated air moving through a bed of cotton. New surfaces are exposed by the tumbling action and for this reason flat bed units for moisture addition are not likely to be as efficient as a moisture addition system that provides tumbling.

Experiments investigating possible error sources in electrical resistance/moisture content measurements showed that: (a) Cotton mass electrical resistance tends to decline slightly with field exposures up to 65 days, but the effect on resistance as related to automatic moisture control systems is negligible; (b) the effect of soil fed Phorate insecticide causes cotton to produce fibers having higher mass electrical resistance than untreated cotton, but the effect of this difference on the USDA-type automatic moisture control system is not significant; and (c) tightlock cotton was found to be electrically similar to normally opened cotton, but tightlock cotton had an equilibrium moisture regain of 10.9 percent at 75 percent r.h. compared to 9.8 percent for normally opened and field weathered cotton.

2. A field study was made by the Mesilla Park Laboratory at a commercial ginnery in Arizona to measure the effects of three levels of seed cotton fiber moisture on roller ginning. The experiment variable was the fiber moisture level of the seed cotton entering the roller gin stands. The moisture levels were obtained by the combined use of drying and moisture addition. All moisture addition was by the injection of warm, high relative humidity air into the extractor-feeders above the gin stands which limited cotton exposure time to a few seconds. The higher moisture level, five percent, resulted in slightly longer fiber staple lengths with fewer short fibers and in slightly decreased seed cotton cleaning efficiency in the extractor-feeders and slightly decreased lint cleaning efficiency.

C. Seed Cotton Cleaning

1. Tests of a tight lock separator at Clemson showed that the device would remove about 8 percent of the tight locks and 25 percent of the burs.
2. Seed cotton cleaning tests at Stoneville showed no important differences in grade when using three rates of feed. Also there was no final foreign matter content differences between treatments. The test brought out that more efficient means of stick and stem removal is needed to prevent their being ground into small hard to remove trash. Tests on individual machines showed that the USDA stick and green leaf machine having restraining grid rods was more efficient in foreign matter removal than the sling-off principle used in most commercial models. Tests also show that a more efficient extractor feeder is needed for machine-harvested cotton. Studies of samples containing extraneous matter showed that the classer cannot always differentiate between bark and grass in lint cotton.

D. Conveying

1. Air-jet conveyor investigations at Mesilla Park were conducted to study the effects of orifice opening size, spacing, and discharge angle on discharge air velocities required to convey seed cotton, cottonseed, and cotton plant sticks. It was found that the critical discharge velocity for a particular material was not constant but depended upon orifice opening size and spacing. For horizontal conveying the orifice discharge angle had little effect upon critical discharge velocity. Prediction equations were developed that relate the air velocity required to convey a particular material to the orifice arrangement of the air-jet conveyor. It was successfully demonstrated that conventional seed augers and seed belt conveyors under saw gin stands could be replaced by simpler and safer air-jet type conveyors. A 6-inch wide air-jet conveyor installed under the laboratory saw gin had no difficulty handling 1300 to 1800 pounds of seed per hour with about the same power requirements as conventional conveyors.

A low-pressure lint cleaner waste collection system under test at Stoneville will replace a comparable size high pressure system and will effect a savings of over 75 percent in power requirements. This new system employs large diameter pipe, a vane axial fan, and a modified lint condenser.

E. Gin Stands

1. Studies at Clemson show that when the gin breast is allowed to remain in ginning position between bales, the cotton ginned as the seed roll collapses will be shorter in staple length and have less desirable color characteristics.
2. Based on studies at Clemson, the total time a seed will remain in the gin roll box will vary from 1.4 to over 10 minutes. A large percentage of the fibers are removed during the first few seconds the seed are in the roll box.

Also, coating the interior of the roll box with teflon gave no increase in capacity although an increase in tangential velocity was noted.

3. Tests made over a 3-year period at Mesilla Park show that nep formation in a saw gin stand is independent of peripheral saw speed. Nep formation increases with seed roll density. High speed movies indicate that there is no reason to believe that the lint doffing operation contributes to nep formation. Based on all the results obtained so far, nep formation in saw ginning is primarily due to actions taking place within the seed roll box. The results strengthen the rule to operate a saw gin stand with as loose a seed roll as possible to obtain highest lint quality.

4. Five different roller gin roll coverings were tested at Mesilla Park in an effort to determine the surface properties which contribute to its ginning ability. The five roller materials tested were: (a) Black rubber; (b) cotton cloth; (c) gray rubber; (d) cork; and (e) rubber and cork. They were adjusted to allow the rollers to gin at a normal rate. The rubber rollers required less than normal roller-to-knife pressure. The cotton cloth roller required more than normal roller-to-knife pressure. The high roller-to-knife kinetic frictional force treatments were also the high ginning rate treatments. The ginning rate appears to be proportional to the roller-to-cotton frictional force (static coefficient of roller-to-cotton friction times the roller-to-knife pressure). The black rubber roller ginned at the highest rate with a low roller-to-knife pressure but it required twice as much power to drive the roller with no cotton present as it did to gin cotton. Rollers with large roller-to-knife coefficients can cause the rollers to over heat if operated without good feed rate control. Although all of the rollers tested ginned at a satisfactory rate, all of the rollers except the cotton cloth roller caused noticeable lint contamination and discoloration due to their high wear rate; however, it required more power to gin than to operate with no cotton. Also, it required higher than normal roller-to-knife pressure to obtain a normal ginning rate. High-speed motion pictures were taken to study the effect of roller-to-knife pressure on ginning rate and roller-to-cotton slippage. It was found that at very low roller-to-knife pressures (one-fifth of normal) the roll slipped on the fibers about 75 percent of the time while at normal pressure (about 30 lbs./in. of roller length) the roller appeared to slip less than 50 percent of the time.

F. Gin Performance and Cotton Quality

1. Quality evaluation tests were conducted at Mesilla Park on Hopicala and DPL-SL varieties grown at two elevations. Conclusions were that the Hopicala had several times as many motes as did DPL-SL, lower turnout, greater tenacity of fibers to seeds, larger seed index, more linters, and higher lint foreign matter content. The higher elevation produced higher turnout, lower tenacity of fibers to seeds, more lint foreign matter content, and greater reflectance. The two elevations did not influence the number of motes.

Mesilla Park studies of cottons ranging from 3.7 to 12.9 percent in linters content showed that relatively low linters content cotton ginned at faster rates, had greater turnout, higher micronaire, and lower tenacity of fibers to seeds.

2. Tests show the Mesilla Park fiber sorter to be about five times faster than the Suter-Webb Sorter. The two instruments compare favorably on measurements of both the long and short fibers in a sample. With groups of upland cottons spun with and without crusher rolls, both instruments correlated favorably with the spinning results. Most correlations were significant at the 1.0 percent confidence level.

At Stoneville three methods of butterflying seed cotton units were used on five different cotton varieties in an effort to make length measurements using the Fibrograph. Ten seed units were placed on each Fibrograph comb for each of the three butterflying methods which were hand combing, USDA blender combing, and compressed air. Most of the upper-half mean lengths were lower than expected or lower than those found in the regular lint tests on the Fibrograph, while the mean lengths were higher than the regular Fibrograph mean lengths. The compressed air method of butterflying showed the most promise for further investigation. Suter-Webb arrays were made on three check cottons before and after adjusting comb spacings to five fiber lengths. In most cases, after the comb spacing was adjusted, individual length group percentages, upper quartile lengths, and short fiber percentages were nearer to the twenty-test averages found by C&MS. When array tests are to be made using the Suter-Webb array combs, it seems advisable to make at least two tests on a check cotton and adjust comb spacing if the individual length group percentage averages are not within two standard errors of those for the check cotton.

3. Tests for aflatoxin on seed collected by the Mesilla Park Laboratory indicated that there appeared to be no relationships between aflatoxin and seed cotton storage, cottonseed storage, methods of ginning to produce good and damaged seeds, varieties, species, extreme temperatures, or times or methods of harvest.

4. Tests at Mesilla Park showed that a change in electrical resistance of 0.6×10^6 ohms per degree F. was obtained in lint cotton using air of 75 percent r.h. corresponding to a lint moisture of about 9 percent and an applied voltage of 30 volts. At temperatures between 75° and 85° F. and an applied voltage of 30 the resistance increased with decreasing temperature. A value of 20×10^6 ohms per degree F. was obtained when using an applied potential of 3 volts.

Preliminary experiments of static electricity effects on cotton were conducted at Clemson. A vertical capacitor was used. Measurements of static deflection of a particle of cotton in different electric fields and relative humidities were made. The deflections were converted into charge and plotted against electric field intensity to show that the maximum charge increased as relative humidity decreased.

5. The Stoneville Laboratory was responsible for the ginning phases of a 10-bale experiment in Texas and a 24-bale experiment in Mississippi. The effect of applying X-78 to cotton at the gin at a rate of 0.15 percent of lint weight was studied. The experiments showed neither damage nor benefit to fiber, yarn, or fabric quality when the additive was applied in accordance with manufacturer's recommendations. Spinning performance may be slightly affected because of an increase in lap-ups and high concentrations of the chemical were shown to cause differences in dyeing. Observations during ginning indicated some reduction in static electricity due to the additive. Spinning and spinning performance evaluation was carried out by the Clemson Pilot Spinning Plant.

At Stoneville investigations were made of irreversible fiber damage caused by time and drying air temperature relationships. This was a continuation of 1966 work. The data showed no difference in proportion of broken fibers (about 11 percent) during fiber/seed separation in 75 percent r.h. between cottons exposed for 30 seconds and cottons exposed for 300 seconds at temperatures from 25° C. to 150° C. At 175° C. (347° F.) 3-seconds exposure had a similar effect as 30-seconds exposure, but 300-seconds exposure caused a highly significant increase in fiber breakage over the 30-seconds exposure. Although the data failed to show statistical significance, heating seed cotton for as little as 3 seconds at 200° C. (392° F.) caused some irreversible fiber damage.

6. Calculating cottonseed moisture. At Stoneville a large number of cottonseed samples were oven dried (10-12 hours) to obtain moisture percentages. Weighings were made after three and five hours of oven drying. From the 3-hour weighings, moisture losses were computed and equations for calculating 10- to 12-hour moisture percentages were developed. Average difference in moisture percentages obtained by using the 3-hour prediction equation ($y = 2.36x + .16$), where x = moisture loss in grams after three hours of oven drying) and 10- to 12-hour percentages were considerably less than the average difference between the 5-hour and 10- to 12-hour percentages. On a basis of these findings, the use of the equation after three hours of oven drying is recommended.

Several equations were developed at Stoneville for calculating lint moisture after oven drying for 10, 15, and 20 minutes. For a moisture range of 3.2 to 8.8 percent, the equation ($y = 5.03x - .51$), where x = loss in grams after 20 minutes plus loss from 10 to 20 minutes drying time) gave calculated percentages with $\pm .7$ percent of the regular 50-minute oven drying method. Equations using less than 20 minutes drying time did not give as satisfactory results. Use of the equation is recommended where quick checks are desirable, such as determining the moisture percentage of lint for checking test conditions and setting driers when specified moistures are desired for test lots.

7. Effect of cultural and harvesting practices. A cooperative test between the Mesilla Park Laboratory and the Shafter Experiment Station investigated reports that the new variety, Acala SJ-1, contained more pin trash than 4-42. A replicated ginning test was made using small lots of seed cotton of the two varieties that had been grown and harvested similarly at three locations in the San Joaquin Valley. Results indicate a trend towards more small trash in the SJ-1. Analysis of trash removed from the two varieties did not reveal any noticeable physical differences in trash between the varieties. Comparative data published in the report of the Regional Cotton Variety Test also indicate an increase in small size trash in the ginned lint when similar harvesting and ginning procedures are used. The data show that, although the per acre yield is higher and the lint turnout is lower for SJ-1, it takes several thousand more bolls of SJ-1 seed cotton than of 4-42 to yield a bale of lint. The relation indicates that when more bolls are harvested more leaf trash such as bract leaves will be contained in the raw material entering the cotton ginning system. Consequently, unless more cleaning or higher cleaning efficiencies are used more "pin" trash will be in the ginned lint.

8. Cooperative studies between the Mesilla Park Laboratory and the Cotton Research Center, Phoenix, Arizona, on picked green vs. defoliated cotton showed that the green-picked cotton usually contained more sticks or stems, fine trash, and motes than did the defoliated cotton. For the entire season grades averaged slightly better for the defoliated cotton than for the green-picked with a constant grade index of 94.0 or SLM; however, during the harvest season the green-picked increased in grade from 89.0 in October to 94.0 in December. Staple lengths showed no significant differences between treatments, and were in the range 33.2 to 34.0 thirty-seconds inch. Ginning capacity averaged the same for defoliated and for green-picked cottons for the entire season at 8.1 pounds of lint/saw/hr. Turnout was greater for the defoliated than for the green-picked cotton (33.8 vs. 32.5 percent). Although there was some static at time of ginning, there were no ginning problems attributable to the harvest treatments.

The Mesilla Park Laboratory conducted tests in cooperation with Plant Pest Control to determine the kill of pink bollworms by roller gin stands with and without lint cleaners. Extra long staple American-Egyptian cotton and upland cotton were ginned at a commercial conventional reciprocating knife gin and at a commercial rotary-knife high-capacity roller gin in Arizona. Hand examination of 60-pound samples of ginned lint showed that from 1 to 171 cottonseed were found in the lint. The seed did not appear to have passed between the knife and the roller. Indications are that they probably fell from the gin stands to the lint conveyor belt. No live or dead larvae were found in the lint or in the seed in the lint, but this seed leakage into the ginned lint may present a hazard to quarantine. It may not be possible to permit flat bales to move from infested to non-infested areas because of this hazard. Moth emergency tests from caged samples of seed cotton, seed, and lint are not yet completed.

Experiments were conducted at Stoneville to compare the effects of various methods and dates of topping and pruning cotton on stalk loading, boll rot, picking efficiency, yield, response to cleaning and ginning, cotton grade, and fiber quality. From a gin cleaning, fiber quality, and market value standpoint, there appeared to be no important advantages from the various topping and pruning treatments as compared to the control lots, and from a harvesting standpoint yield was significantly lower for the late side-pruned and topped, plus side-pruned treatments.

Experiments were conducted at Stoneville to compare the effects of defoliation and desiccation treatments on cotton to determine if defoliation and desiccation of cotton is really necessary, and which treatment or degree of treatment provides best response to cleaning and ginning and gives highest quality cotton and the best mechanical picker performance. From a gin cleaning, fiber quality, color value, and market value standpoint, the experiments this year failed to show any important advantages in the defoliation and desiccation treatments as compared to the undefoliated control cotton.

Studies were continued for the third year at Clemson to evaluate seed cotton conditioning and cleaning treatments for spindle-picked and machine-stripped cotton under Southeastern conditions. When results from two years at each of two locations were averaged, the stripper returned about nine dollars per acre more than the picker, based on gross value of the lint and seed.

Differences are attributed primarily to levels of harvester efficiency. However, fiber and spinning tests showed that the stripped cotton was lower in fiber quality and did not spin as well as the picker cotton. This was usually evidenced by higher picker and card waste, lower yarn appearance, lower break factor, more ends down, lower yarn strength, and more imperfections in the yarn. Although the stripper cotton was generally inferior to the picker cotton in fiber quality and spinning performance in this study, it is concluded that under favorable weather and plant conditions the stripper cotton would perform satisfactorily in the spinning process, especially with the addition of a second stage of overhead extraction in ginning.

G. Lint Cleaning

1. Experimental studies were conducted at Stoneville to determine the effect of lint cleaner combing ratio, saw-cylinder speed, and feed roller speed on foreign matter removal and on fiber length distribution of cleaned lint. One hundred test lots were processed through an experimental lint cleaner in five replications of five saw speeds and four feeder speeds. Saw-cylinder speeds employed were 400, 600, 800, 1100, and 1400 r.p.m. with feed roller speeds of 68.3, 91.0, 136.5, and 273.0 r.p.m. These speeds provided a combining ratio range varying from 6.2 to 87.4. The study indicated that lint cleaning at saw-cylinder speeds of 1400 r.p.m. (4398 feet per minute rim speed) gives considerably more fiber breakage than 800 and 1100 r.p.m. speeds and a highly significant increase in neps while producing no significant increase in neps while producing no significant increase in foreign matter removal or increase in grade. Saw-cylinder speeds of 400 to 600 r.p.m. (1257 and 1885 feet per minute rim speeds) gave lower fiber breakage and

fewer neps, which were generally not significantly lower than for the 800 and 1100 r.p.m. speeds, but produced significantly higher foreign matter contents and lower grades. Therefore, for maximum foreign matter removal commensurate with minimized changes in fiber length, the saw-cylinder speed of 800 r.p.m. to 1100 r.p.m. (2513 to 3456 feet per minute rim speed) is recommended, the 800 r.p.m. speed preferred from a fiber breakage standpoint. Feed roller speed should be such that the proper combing ratio is maintained in respect to the above recommended saw speeds. Combing ratios of 12.5 to 37.5 are desired. Higher ratios gave high fiber breakage and nep counts and lower ratios considerable decrease in cleaning efficiency.

A study was conducted at Stoneville to determine the effect of saw-cylinder lint cleaners upon seed coat fragment and funiculi removal and upon the distribution of the fragments as to size, weight, and number. Number of lint cleaning stages employed were none, one, two, three, and four. These experiments showed:

(1) In a seed coat fragment size distribution the total weight of the larger fragments was greater than the total weight of the smaller fragments.

(2) Lint cleaning shifts the seed coat fragment size distribution toward the smaller fragments. Fragments larger than 5 millimeters in length are removed readily, almost none remaining in the cleaned lint after two lint cleaners. Smaller fragments were the most difficult to remove.

(3) One lint cleaner gave a significant reduction in fragment weight but no further significant reduction between one and two lint cleaners. No significant differences in fragment number were attributed to lint cleaners.

(4) One and two lint cleaners both gave significant decreases in the funiculi (weight and count) remaining in the lint. No significant differences were observed between two and three lint cleaners.

(5) Funiculi size remained fairly constant during lint cleaning. Funiculi were removed at a faster rate than fragments.

(6) A considerable number of fragments and funiculi remained in the lint even after four lint cleaning stages.

The feasibility of increasing the moisture content of cotton for lint cleaning was studied at Stoneville by doffing lint from the gin saws with humid air at various relative humidities. This moisture addition proved to be operationally sound when the relative humidity of the doffing air did not exceed about 85 percent. Higher humidities caused condensation on gin machinery and disruption of cotton flow. Cotton ginned at 4.5 percent lint moisture content was increased to 6.3 percent and that at 6.0 percent to 7.6 percent during the 3.6 seconds exposure time. Some increase in the lint foreign matter level was noted with doffing air at 90 percent relative humidity. Generally, grade indexes and grade were not affected by the moisture treat-

ments. Differences in staple length for all moisture treatments were less than one-thirty-second of an inch.

H. Packaging

1. Tests at Stoneville proved that principles to form and roll up a lap of cotton at a density in excess of 22 pounds per cubic foot are sound and that full-size equipment may be designed with a high degree of confidence.

I. Waste Collection and Disposal

1. Extensive collection efficiency tests on small-diameter type cyclones were conducted over a wide range of operating conditions at Mesilla Park. It was found that the collection efficiency of a small-diameter cyclone was 99.9 percent and higher when collecting ordinary gin trash under normal operating conditions. Efficiencies of 99.1 to 99.6 percent were obtained when collecting fibrous-type waste such as condenser exhaust waste, motes, and lint cleaner trash. These test data also showed that the cyclone's collection efficiency increased slightly as the trash input increased. This trend was apparent until the input rate increased to the point that trash began to bridge at the cyclone trash exit. It was also found that increasing the cyclone inlet air velocity from 2200 to 4800 feet per minute decreased collection efficiency due to increased turbulence encountered at the higher air velocities.

Problems with an experimental centralized condenser exhaust filtering system at a local commercial gin plant were corrected by replacing the existing troublesome and complicated air filtering unit with inline air filters. This system performed satisfactorily throughout the ginning season. The only problem of any consequence was in disposing of the waste material after it had been collected.

An attempt to reduce air pollution inside the gin room by using a slotted suction duct near sources of dust and fly lint emission was not successful. A suction duct placed around the charging box of the press did not materially reduce dust and fly lint concentrations in the air.

Air from the unloading fan in the Clemson Laboratory was exhausted into an experimental three-section inertial separation chamber in efforts to reduce the amount of pollutant material emitted to the atmosphere. Addition of water spray to the chamber reduced the amount of material emitted from the chamber by as much as 92 percent. Concentration of pollutants at the chamber exhaust ranged from 14,065 to 109,922 micrograms per cubic meter during dry operation and from 2605 to 38,093 micrograms per cubic meter during wet operation.

Microscopic analysis of material collected on filters indicate a majority of the particles exhausted from the separation chamber to be less than 50 microns in diameter. Generally, particle size on each filter ranged from 2 to 50 microns and the average particle size of filters ranged from 6.9 to 16.5

microns. Particle shape varied considerably but elongated rod and circular shapes were most predominant. Fungi represented as much as seven percent of the total particles on individual filters.

The air in the neighborhood of a cotton gin was randomly sampled by Clemson personnel on both the sucker pipe and emission side of the gin in a predesigned pattern with the objective of determining the distribution of particulate matter emitted. Two high volume samplers were used with fiber glass filters advertised as 99.9 percent efficient for particles exceeding 0.3 microns. Relative humidity, temperature, wind direction, and wind magnitude measurements were made. The concentration values ranged from near 0 to 16,000 micrograms per cubic meter, and the size of the particulate matter obtained from a microscopic examination generally averaged less than 20 ± 10 microns.

Air pollution control devices at commercial gins in the Southeast consist primarily of ginner-designed systems, most of which are inadequate and poorly maintained. Cyclones, both small and large diameter, and settling chambers are the most often used means of control. Trash incineration is practiced on a limited scale. Air samples obtained at exhaust vents of cyclones at the Clemson Laboratory indicate large numbers of small size particles released to the atmosphere. Dust concentration at a point 18 inches from edge of exhaust vent ranged from approximately 3000 to 6350 micrograms per cubic meter. These particles are usually released at heights of 15 to 30 feet and, therefore, are subject to widespread dispersal and prolonged suspension in the atmosphere. Dust concentration within the gin varied considerably during processing. Concentration at a point 10 feet from gin stand ranged from 200 to 2700 micrograms per cubic meter and at a point 20 feet from gin stand the concentration ranged from 60 to 770 micrograms per cubic meter. These concentrations were present within the gin even though air intake of fans within the gin exceeded 20,000 c.f.m. A small fan (6-inch inlet diameter) used in conjunction with a pipe system with small diameter holes or vents did not materially reduce dust concentration near two unit saw type lint cleaners.

Research is underway at Stoneville to find an economical means of reducing the pollution in condenser exhausts sufficiently to return the air into the gin building. Two air filter systems were tested on the exhaust of the lint slide condenser vane axial fan. The first system consisted of two stages. The first stage was a 100 x 100 mesh screen and the second was a 2-inch thick fiber glass media. Total static pressure load for the system was set at one inch of water and the dust concentration was reduced from 11,000 to 257 micrograms per cubic meter of air. The replacement cost of the fiber glass media was \$0.063 per bale. The second filter system was a single stage polyurethane foam media type which was doffed by a vacuum nozzle. The static pressure load for this system was 0.5 inch of water and the dust concentration was reduced from 11,000 to 365 micrograms per cubic meter of air. Replacement media cost has not been determined.

A low pressure lint cleaner trash collection system was designed for use in the gin at Stoneville which would affect power savings, and clean the air sufficiently for it to be returned to the gin building. Operational tests showed that the collection of lint cleaner waste with a low pressure pneumatic system and a condenser instead of a cyclone, is possible at about one-fourth the power requirement of present day high pressure systems. Filtering the air with a fiberglass type filter is possible but media replacement cost of 38 cents per bale makes it prohibitive.

The suspended particulate matter being discharged from the filter averaged 606 micrograms per cubic meter of air. Further work will be directed toward more efficient filters for the system.

Tests at Clemson showed a centrifugal dry-type separator is most inefficient for the collection of material-exhausted from a battery condenser. The average of three tests showed that only 42 percent of all fibers were separated from the air. An average of 8.8 percent of all fibers fed adhered to the impeller blades and housing.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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Wilmont, C. A., and Watson, Harold. 1966. Power Requirements and Costs for High-Capacity Gins. USDA-Marketing Research Report No. 763, July.

Lint Cleaning

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Cottonseed

Moore, V. P., and Shaw, C. S. 1967. Mechanical Damage to Cottonseed-Ginning Effects. Cotton Gin and Oil Mill Press, Vol. 68, No. 5, March 11.

Waste Collection and Disposal

Baker, R. V., and Stedronsky, V. L. 1967. Collection Efficiency of Small Diameter Cyclones. Cotton Gin and Oil Mill Press, Vol. 68, No. 12, June 17.

McCaskill, O. L., and Moore, V. P. 1966. Elimination of Lint Fly, A Progress Report. Cotton Gin and Oil Mill Press, Vol. 67, No. 27, December 31.

Moore, V. P., and McCaskill, O. L. 1967. Methods of Collecting Seed Cotton Trash. Public Health Service Bulletin No. 999-AP-31, Environmental Health Series, Air Pollution.

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Watson, Harold, and Holder, S. H. 1966. Reclaiming Gin-Loss Cotton. USDA-Production Research Report No. 91, June.

AREA NO. 7. STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. The magnitude and scope of the crop and machinery storage problem is evidenced by the vast quantities of crops and other materials handled and stored on the farm. Annually on the farm: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly one billion is carried over from the preceding year; (2) 208 million tons of hay and silage are processed and stored; (3) nearly 2.5 million bushels of apples and pears and 34 million hundred-weight of potatoes and sweet potatoes are held for food, feed and seed; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. An aggregate total of more than seven million tractors, combines, corn pickers, and other expensive farm machines need storage and repair buildings to maintain operating efficiency.

Farming methods are continually changing, requiring new information to be developed to keep storage structure design abreast of the cropping practices. For example, crops are being harvested, handled, and stored in new forms such as high moisture shelled corn, wafered forage, and low moisture silage.

Plant growth structures can represent investments ranging from a few hundred to several million dollars depending on their nature and scale. Controlled environment growth chambers range from \$1000 to \$50,000, controlled environment greenhouses from \$2000 to \$700,000, and phytotrons from \$400,000 to \$5,000,000. During the last several years, the USDA has spent about \$500,000 per year for growth chambers. No overall expenditure figures are available.

The 1959 census showed 227 million square feet of commercial greenhouse area in the United States. Of this area, 83% is used for florist crops, 4% for nursery crops, and 13% for vegetable crops. Greenhouse produced crops equal 2% of all farm products sold.

Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions actually maintained in these units. There is urgent need to develop engineering design criteria for constructing and equipping chambers that will reliably provide and maintain desired thermal, lighting, and other environment over a wide range of experimental conditions. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type-plant growth structures.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

A. Crop Storage Structures (silos and bins). Research is cooperative with Animal Husbandry Research Division, ARS, at Beltsville, Maryland.

B. Plant Growth Structures (environmental chambers and greenhouses). Research at Beltsville, Maryland, is cooperative with Crops Research Division, ARS.

C. Plan Development Typical plans for crop structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

The Federal effort in this research area totals 2.5 scientific man-years. Of this number 0.9 are devoted to crop storage structures; 1.0 to plant growth structures; 0.4 to plan development and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment, and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations.

The current broad scale program is concerned with conditioning and storages for high moisture grains; curing, bulk handling, and storage for onions; curing and storage sheds for tobacco; structural characteristics, wall pressures, design and construction of silos; Irish potato and sweet potato plant production facilities and storages; controlled atmosphere storages and construction methods; design for machinery sheds and farm service buildings; and designs and construction of plant growth chambers and plastic greenhouses.

Much of this research activity is cooperative with the Department.

A total of 11.0 scientific man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Crop Storage Structures.

1. Silo design criteria. In studies at Beltsville, three silo wall types (1) open, (2) concrete, and (3) metal -- were compared for storage loss of alfalfa silage in a small-scale, 29 day test of wall permeability. Sealed metal and concrete walls gave essentially complete recovery of dry matter regardless of distance behind the wall, while with an open wall, recovery increased with both increasing distance from the wall, up to about 67cm, and with increasing dryness of loaded forage; at each of three dryness levels, recovery at 67cm from the wall was about equal to that in sealed or concrete containers. Combined data for three dryness levels showed a slightly greater recovery from sealed metal than from concrete walls. Protein recovery tended to follow the trends of dry matter recovery except that it increased with increasing dryness with all walls. pH values were slightly lower with sealed walls than with concrete, and minimum in both occurred at .4 dry matter fraction. With open walls, minimum pH occurred at below .3 dry matter fraction.

Work on determination of forage density in normal storage conditions, using a radioisotope, has been completed.

2. Comparison of wilting with other harvest treatments. In studies at Beltsville, alfalfa was ensiled for comparative storage evaluation of 3 harvest treatments: Direct-cut, mechanical dewatering, and wilting, in cooperation with other ARS units and a manufacturer which supplied a prototype dewatering machine. Compared to direct-cut, forage mass per unit of dry matter was reduced 20% by dewatering, and 55% by wilting. Dewatering removed 11% of the crop dry matter, and that forage lost 6% more dry matter in silo juice, while the direct-cut lost 16% in silo juice. Fermentation loss was slightly greater in direct-cut although silage temperatures indicated nearly identical fermentation processes. Feed dry-matter recovery was estimated as: Direct-cut 77%, dewatered 78%, wilted 96%, of the crop. Respective protein recoveries were 73%, 65%, 92%. Dewatering did not significantly improve preservation over direct-cut; wilting was superior to both. Dewatering removed a disproportionate amount of protein. Storage space utilization density was calculated as 6.7 lb/cu.ft. and 10.0 lb/cu.ft. for direct-cut and wilted, and estimated as 7.0 lb/cu.ft. for dewatered silage. In this experiment wilting was by far the best preparation for ensiling.

3. Hay wafer storage. At Beltsville, cylindrical rolled hay wafers were tested for ease of storing and moving, and compared to cubical extruded wafers. Rolled wafers were about as susceptible to molding in drying storage as baled hay, but less so than extruded wafers. Rolled wafers had massing characteristics similar to extruded wafers, but were slightly less coherent and therefore slightly more easily moved. No further work is contemplated.

4. High moisture shelled corn storage. Inactive during reporting year.
5. Grain bin pressures. Inactive during reporting year.

B. Plant Growth Structures

1. Phyto-Engineering Laboratory. Construction of the Phyto-Engineering Laboratory at Beltsville was sufficiently completed to permit occupancy in June 1966. Major effort during the remainder of the reporting year was devoted to procurement and installation of environmental control equipment. The first planned controlled - environment experiment was started during March 1967.
2. Carbon Dioxide Studies. Addition of CO₂ gas in plexiglass test chambers at Beltsville has given additional growth and earlier flowering in nearly every type of plant studied. Addition of carbonic acid (soda water) gave consistently negative results rather than earlier flowering and accelerated growth--as suggested from results of tests by others. Differences may be due to soil types, water hardness, solar radiation, temperature, management or a combination thereof.
3. Motion meter. Work over a period of 2 years at Beltsville has resulted in development of a highly sensitive (5×10^{-4} inches change in position) motion meter for continuous detection, measurement and recording of the movements of plants during either day or night with very little disturbance to the plants. The meter has been used successfully to measure sensitive plant (mimosa) cyclic movements geotropism, and leaf thickness.
4. Portable Greenhouse Conditioning. An experimental, 16'x40' self-contained, temporary, prefabricated, plastic-on-wood- frame, greenhouse for maintaining controlled (or partially controlled) conditions for short-or-long-term experiments on fruits, vegetables, or ornamental plants that was developed last year was successfully field tested over pear seedlings being treated for Fire Blight disease. An L-P gas engine-electric generator set supplied electricity for controls, water pumps, and ventilation fan.

C. Plan Development At Beltsville, Plan No. 5980, "Plant Growth Chamber Roomette," was completed and issued by the Cooperative Farm Building Plan Exchange.

PUBLICATIONS --- USDA AND COOPERATIVE PROGRAMS

Plant Growth Structures

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Plastic greenhouse with partial environmental control for horticultural research. Proceedings, Seventh National Agricultural Plastics Conference.

Cathey, H. M., Klueter, H. H., and Bailey, W. A. 1967. Indoor gardens for decorative plants. USDA Home and Garden Bulletin. (unnumbered)

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AREA NO. 8 RURAL DWELLINGS

Problem. The Presidential housing message, January 1964, stated that more than a million rural families still live in homes of such poor condition that they actually endanger the health and safety of the occupants; 3 million rural families live in homes that need major repairs; a third of our rural homes do not have complete sanitary facilities; and nearly two-thirds are without adequate heating. The Census of Housing shows rural housing as a whole to be older than, and inferior to, urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. Large numbers of houses outside of cities and towns remain without the convenience and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or workers, either full-time or seasonal. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials and use of more efficient and self-help construction methods. The Farmers Home Administration program of rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. Further research is also needed on design and equipment of houses for improved control of temperature, air movement, and economy of operation and maintenance.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems similar to those of farmers, and the housing research of the Department is applicable to them. Engineering research on design of equipment for senior citizen housing is also needed.

Programs for bringing in foreign agricultural workers to supply the short term peak labor needs associated with many of our farm crops, particularly fruits and vegetables, have expired. These labor needs are now being filled predominately with domestic seasonal and migratory workers. These domestic agricultural workers tend to travel in family groups more than did the foreign workers and thus have changed the pattern of housing requirements. In addition, public health agencies are concerned that the housing provided for these workers be adequate and sanitary so as to reduce the hazard of spreading disease - among themselves, or among residents or communities in which they work, through contacts with the crops they are handling.

There is also a trend toward community - and grower associations camps, with greater child care, health service and semi-skilled job training programs incorporated.

An individual producer is concerned that his facilities be as inexpensive as possible in order to hold down his production costs and maintain his competitive position. In view of this, there is need for research to develop design criteria for adequate housing and related facilities for these workers and their families, particularly where the term of occupancy is short - 2 to 4 weeks per year.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans and planning guides for rural dwellings of all types. A program of evaluation and development of construction plans and utilization of low-cost housing for seasonal and migratory farm workers is being conducted for U.S. Public Health Service under a reimbursable agreement dated March 22, 1965.

A. Design Criteria for Comfort, Health and Safety. Research at Athens, Georgia, on determination and evaluation of thermal and sound effects of soft window and floor coverings, is in cooperation with the Georgia Agricultural Experiment Station. Development of planning aids at Athens, Georgia, is cooperative with the Georgia Station.

B. Materials and Construction. An experimental structure for developing and evaluating low-cost floor deck and slab construction is located at Plant Industry Station, Beltsville, Maryland. Prototype low-cost houses have been constructed at Charles Town, West Virginia, and one has been started at Oakland, Maryland, to evaluate new design features.

C. Systems for Environmental Control. A study to determine the optimum arrangement for an attic fan to reduce summer temperatures economically is underway in Athens, Georgia, in cooperation with the Georgia Station. Experimental low-cost plenum warm air heating systems are being evaluated in prototype houses at Charles Town, West Virginia.

D. Rural Housing Design Development. Architectural design and preparation of rural housing plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville, Maryland, in cooperation with the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and State Experiment Stations make the plans available to the public. Farmers Home Administration consults on requirements and also makes plans available to its clients. The Public Health Service, USDHEW, is cooperating in development of designs for housing facilities for seasonal and migratory agricultural workers.

The Federal effort in this research area totals 5.1 scientific man-years. Of this number 1.2 are devoted to design criteria for comfort, health, and safety; 0.1 to studies of materials and construction; 0.6 to systems for environmental control; 2.8 to development and preparation of improved rural housing designs; and 0.4 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 10.9 scientific man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Design Criteria for Comfort, Health and Safety.

1. Thermal Control. The laboratory study at Athens, Georgia, on the effect of window and floor coverings on heat transfer and environmental factors (dry bulb temperature, radiation, and air motion) is nearing completion. Heat transfer tests showed all window coverings relatively ineffective in reducing loss through windows unless sealed tightly at all edges. Draperies hung in normal fashion may increase heat loss due to increased velocity of air flow over top and discharge at bottom. A plasticized cloth roller shade sealed around all edges was most effective in reducing heat loss. Data from tests to determine heat transfer coefficients of carpets with and without underlays have not yet been analyzed.
2. Noise Control. In the laboratory at Athens, Georgia, 12 carpets differing in fiber content, pile weight and height, and surface construction with three different underlays; and five different drapery materials were studied in a reverberation room to determine effect of interior soft coverings on sound levels in homes. Without underlays, only three heavy weight carpets were significant sound absorbers. With underlays, all carpets except two with foam rubber underlay were. Foam rubber was less effective than hair-jute underlay. Heavy weight pattern loop carpets were more effective than cut pile or plain loop. Surface construction made little difference in lighter weight carpets. Cotton, rayon and rayon-acetate lined draperies, pleated to 50 percent of unpleated width were significant sound absorbers. Fiber glass was only slightly less effective. Differences between pleated and unpleated draperies were significant. Significant differences resulted between frequencies. Laboratory work has been completed and technical bulletin manuscripts are being prepared.
3. Planning Aids. Final draft of manuscript for House Planning Aid, "Making Basements Dry," has been completed. Manuscripts on the following titles remain in preliminary draft pending availability of effort to complete: Foundations and Walls," Wood Framing," "Selecting Exterior Coverings," "Summer Cooling for the Farmhouse," "Residential Carports and Garages," "Post-and-Girt Wall Framing For Houses."

B. Materials and Construction

1. Low-cost floor deck and slab studies. The nonconventional significant floors installed at the South Farm, Beltsville, Maryland, have now been in place for about 4 years. Evidence is that there has not been a build up in moisture under these floors or in the flooring materials during this time. Sometime in the near future, it is planned to remove sections of these floors to determine their present condition.
2. Prototype low-cost house construction. Prototype House #2 at Charles Town, West Virginia, was completed, finished on the inside, and prepared for testing the warm air plenum heating system. A third house listed as Prototype #3 located at Oakland, Maryland, was started in the spring of 1966 and the shell completed except for windows. This house is a large pole-type structure 44' long and 32' wide containing 3 bedrooms, a large living room, and a small kitchen. It has a partial basement used for the heating plant, hot water tank, and other purposes. The fireplace and chimney are being constructed at one end of the living room, providing the possibility for future tests with a deep fire pit, which may be classified as an efficient fireplace, and could actually be used for heating. Information on this prototype has indicated that there are limitations on the size of house for easy or efficient pole construction.

C. Systems for Environmental Control

1. Attic fan cooling arrangements. At Athens, Georgia, study of arrangement and operation of attic fan systems in relation to placement of insulation has been completed and is being statistically analyzed. Beneficial effects of forced ventilation cannot be totally measured by temperature reduction alone because of the cooling effects of air motion over the body. Unfortunately, where all factors are not controllable and cannot be duplicated exactly it is not feasible to determine the total effect. Conclusions as follows are based on observations of averages and deviations from averages: (1) forced ventilation with attic fan gave slight temperature advantage over natural ventilation without fan; (2) ceiling insulation resulted in lower inside room air temperatures than roof insulation with attic ventilated in afternoon and rooms at night; (3) with ceiling insulated there was a very slight temperature difference in favor of ventilating attic in afternoon and rooms at night as compared with ventilating rooms only at night; (4) with windows closed in morning and open in afternoon and night, and with the fan ventilating attic in afternoon and rooms at night a slight temperature reduction resulted as compared with windows open 24 hours per day. This might not be true where large glass areas are exposed to morning sun. A publication is being prepared. The information will be of value to builders and home owners where natural air cooling is preferred to mechanical cooling and where the latter cannot be afforded.
2. Warm air heating plenum. At Charles Town, West Virginia, prototype House #2, 2 stories of pole type construction 32'x24' was completed and heating

tests run with the under-floor plenum-perimeter slot heating system. In this house a down-draft furnace, operating on a thermostat, and a hand-fired, radiant-type wood stove having a thermostatic damper were used--at times independently and at times together. The system is arranged to deliver air to or take air from any of four areas of the house. Data have been taken and are in table form, not yet analyzed except for spot checks. Preliminary indications are very favorable, with quite uniform temperatures in all areas of the house.

D. Rural Housing Design Development

1. Farm and rural dwellings. At Beltsville, Maryland Plan No. 7182 for a three-bedroom tenant house was completed and released--two other plans are under development. Miscellaneous publications describing 6 farm house plans ranging in size from 2 to 5 bedrooms, were issued. Two others are in preparation.

2. Seasonal and migratory agricultural worker housing. Major effort was devoted to development of designs and building of experimental prototype structures for housing migratory agricultural workers to obtain performance data under service conditions. Arrangements have been made with growers in Florida, South Carolina, West Virginia and Maryland to cooperate in building prototype structures for housing their migratory agricultural workers. Construction is progressing on a cooperative basis in two localities. Eleven plans for housing units for migrant families, developed from research, have been finalized and are in process of being published for nationwide distribution. In cooperation with the Public Health Service, USDHEW, and the U.S. Department of Labor, progress has been made in amending health and building codes covering migrant housing as the result of research and experience.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Design Criteria for Comfort, Health and Safety

Haynes, B.C., Jr., 1967. High Speed Low Power Level Commutator.
ARS 42-127, January

Materials and Construction

Rule, R. H., 1966. Making Basements Dry. Home and Garden Bulletin No. 115
October

Newman, Jerry O. A House Framing System for Low-Cost Construction. 1966.
Miscellaneous Publication 1020. August

Rural Housing Design Development

Agricultural Engineering Research Division. 1966. Three-bedroom Farmhouse.

(Exchange Plan No. 7168) Miscellaneous Publication No. 1016. April.

Agricultural Engineering Research Division. 1966. 1 1/2 Story Dwelling.

(Exchange Plan No. 7179) Miscellaneous Publication No. 1034. October.

Agricultural Engineering Research Division. 1966. Five-bedroom Rural

Dwelling, (Exchange Plan No. 7181) Miscellaneous Publication No. 1038.
September.

Agricultural Engineering Research Division. 1967. Two-bedroom Farm Dwelling.

(Exchange Plan No. 7176) Miscellaneous Publication No. 1042. January.

Agricultural Engineering Research Division. 1967. Three-Bedroom Rural

Dwelling. (Exchange Plan No. 7180). Miscellaneous Publication No. 1048.
February.

Agricultural Engineering Research Division. 1967. Three-Bedroom Tenant House.

(Exchange Plan No. 7178) Miscellaneous Publication No. 1049. February.

AREA NO. 9. LIVESTOCK ENGINEERING (EXCEPT ELECTRICAL)

Problem. The American farmer has about \$14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another \$1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their effort to reduce production costs and improve product quality. These trends are demanding more basic knowledge about the effects of environment on the health, growth, production and fertility of livestock; about structures and related equipment for maintaining desirable environments; and about methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that will provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency.

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, and growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern. Information is needed on means for keeping these residues from adversely affecting the animals or their products.

Labor is an important element in production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to livestock production enterprises. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the Animal Husbandry, Animal Disease and Parasite, and Entomology Research Divisions of ARS, USDA, and is a contributing project to cooperative Regional Research Project NE-8, "Essentials of Poultry Housing for the Northeast." Plan development work is cooperative with all the State Colleges through Regional Committees, and with FES, as part of the Cooperative Farm Building Plan Exchange.

A. Dairy Cattle Engineering. Dairy cattle environmental and bioengineering studies are conducted in a climatic laboratory at Columbia, Missouri, in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. The influence of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are studied in cooperation with the California Agricultural Experiment Station. Typical plans for dairy structures are developed at Beltsville, Maryland.

B. Beef Cattle Engineering. Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Typical plans for beef structures are developed at Beltsville, Maryland.

C. Swine Engineering. Swine structures and equipment research for hot, dry climates is in cooperation with the California Agricultural Experiment Station at Davis and for hot, humid regions at Tifton, Georgia, in cooperation with the Georgia Coastal Plain Experiment Station and AH, ARS, on an "occasional visit" basis. (currently inactive). Typical plans for swine structures are developed at Beltsville, Maryland.

D. Poultry Engineering. Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Maryland, in cooperation with AH, ARS, and the basic laboratory data are applied to experimental poultry houses of the NE-8 Regional Project for evaluation. Limited field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Agricultural Experiment Station and AH, ARS. Environmental influences on health and housing requirements are investigated in new laboratories at Athens, Georgia, and State College, Mississippi, in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minnesota, a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is underway in cooperation with the Minnesota Agricultural Experiment Station. Typical plans for poultry structures are developed at Beltsville, Maryland.

E. Extracorporeal Irradiation of Farm Animal Blood. Research to develop new techniques and equipment for studying blood diseases of farm animals at Beltsville, Maryland, and Ames, Iowa, in cooperation with ADP and Atomic Energy Commission.

F. Radiosity Studies. Studies of radiosity (total radiation) of the sky, ground and surroundings are conducted at Davis and elsewhere in California, and at Columbia, Missouri, in cooperation with the respective Agricultural Experiment Stations.

G. Reducing Pesticide Residues in Animal Products. Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, and College Station, Texas, in cooperation with ENT, and ADP, ARS, and the Texas Agricultural Experiment Station. Program is being developed for the engineering aspects of research in the planned Southwestern Veterinary Toxicology and Livestock Insects Research Laboratory at College Station, Texas.

Federal research effort in this area totals 10.6 scientific man-years. Of this number 2.1 is devoted to dairy; 1.2 to beef; 1.4 to swine; 3.6 to poultry; 0.1 to extracorporeal irradiation of farm animal blood; 0.0 to radiosity studies; 1.5 to reducing pesticide residues in animal products; and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

There is an extensive program of both basic and applied research underway at the State Agricultural Experiment Stations in an effort to provide the answers to the continuing series of questions being raised by livestock producers. Demands are being made for more information on the effects of environment on the physical well-being of all classes of livestock, and the way such optimum environments can be economically achieved; on new approaches to meet the growing labor shortage; on methods to adapt existing structures and equipment for greater economy of production; and on structures and related equipment for improved efficiency of feeding and materials handling operations.

Studies are being made on the effect of environment on the health, growth, production and fertility of dairy cattle, beef cattle, poultry and swine. Equipment and systems for efficiently transporting feedstuff into and out of storages and automatically mixing and feeding complete rations are being developed.

Exploring methods for improved care and housing of farm animals with greater economy and labor efficiency are also in progress as well as investigation of ways to modify existing structures and equipment to meet present-day economic conditions.

Much of the work is cooperative with the Department.

A total of 37.8 scientific man-years effort is devoted to this work.

PROGRESS --- USDA AND COOPERATIVE PROGRAMS

A. Dairy Cattle Engineering.

1. Increasing Efficiency of Operations. At Davis, California, studies in cooperation with the State Agricultural Experiment Station, to determine the effectiveness of herringbone milking parlors in reducing the labor requirement in large-scale dairy enterprises were conducted. Data are being analyzed and prepared for publication. Findings to date indicate that although any size herringbone layout may be suitable for milking cows the most satisfactory sizes are: (1) a (2-4) and one operator if he also moves cows from corrals to milking area and return, (2) a (2-8) for two operators if they move cows, (3) a (2-12) for three operators if they move cows, (4) a (2-5) for one operator if he is above average, (5) a (2-10) for two operators if they are above average. Variables which have the most influence on suitability of a specified herringbone size are (1) the milking operator, (2) milking equipment, (3) milk production, (4) a cow's natural milking speed, (5) arrangement of milking area for optimum use of the above variables.

Farmstead planning, covering overall farmsteads, is discussed in AREA 10 E.

2. Bio-engineering Studies. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory, and related facilities, at Columbia, Missouri, in cooperation with the Missouri Station. The investigation into the effects of total barn air conditioning for dairy cows under commercial herd practices was continued during the summer of 1966. Two groups of 16 cows were again used in a switch-back design (three-week periods, with three reversals). However, neither group was provided air conditioning in this third year of the study; the objective during 1966 was to estimate the effect, if any, of the enclosed barn and more intensive management practices when compared to the dry-lot confinement system. Results showed essentially no differences in milk production under the two confinement systems. This indicates the significant increases in milk production obtained in 1964 and 1965, when air conditioning was provided, were due primarily to the improved climatic environment rather than housing or management practices. Dairy cow activities recorded under the two systems indicated the dry-lot cows spend less time eating during the day in hot weather. They were also more restless. Heat sensitivity studies were continued during the summer of 1966. The heat sensitivity indicator (rate of rise of rectal temperature) has more variability than desirable, leading to the conclusion that a minimum of two tests may be necessary before using the test as a basis for selection. Dairy herd owners have for many years needed a rational basis for determining the amount of shelter to provide their lactating animals. Research in the Missouri Climatic Laboratory has provided general guides by relating milk production

to selected climatic variables, but such results per se do not provide a clear-cut basis for decision-making. By linking the production response of the animal to the probability of occurrence of the weather event determined from climatological records, the probability of a given production response can be found. This probability would then give the dairy herd owner a rational basis for decision. Using this approach, expected summer production losses for Holstein dairy cows of three production levels in the mid-Missouri area were computed, based on Temperature-Humidity Index records. Total expected production loss per cow for the "summer season" considered (June 1 through September 30) was determined to be:

51 lbs for 30 lb/day production level,
88 lbs for 40 lb/day production level.
127 lbs for 50 lb/day production level,

Thus, an owner near Columbia, Missouri, could estimate the economic potential of providing alternate methods of alleviating production decline through providing a more nearly optimum environment.

A study on the role of infused epinephrine and norepinephrine solutions in heat dissipation by the dairy cow showed both to have a strong influence on moisture dissipation at high environmental temperatures (95°F, 50%RH). At moderate conditions (65°F, 50%R.H.), epinephrine still exhibited a strong reaction, but norepinephrine did not evoke a response. Other physiological parameters were recorded, and the results are being processed.

Comparisons of volatile fatty acid (VFA) concentrations (the main fuel for rumination) were made in non-lactating cows at ambient temperatures of 18.2° and 35.0°C and intraruminal temperatures of 43.4° and 51.0°C. The 43.4°C intraruminal temperature with an ambient temperature of 18.2°C caused a highly significant increase in VFA concentrations when compared to concentrations at normal rumen temperature and 18.2°C ambient. A 51.0°C intraruminal temperature with an ambient temperature of 35.0°C resulted in a highly significant decrease when compared to the concentration measured at normal rumen temperature and 35.0°C ambient.

3. Plan Development. No plans for dairy cattle structures were developed during the reporting year.

B. Beef Cattle Engineering

1. Hot, Arid Climates. These investigations were conducted at Davis, Firebaugh and El Centro, California, in cooperation with the California Agricultural Experiment Station (Animal Science and Agricultural Engineering Departments), a beef cattle producer at Firebaugh, and the Madera County Agricultural Extension office.

A test was conducted during the summer at Davis (121 days) to study the effect of shade and animal space on beef cattle production. There were 12 Hereford steers per pen. The table below shows the treatments and a

summary of results: There were no differences in animal responses in the

Pen No.	3	9	10	11	12
Pen Floor	Concrete	Concrete	Concrete	Dirt	Dirt
Pen Size	40x80 ft.	16x30 ft.	16x30 ft.	55x30 ft.	55x30 ft.
Pen area/steer	265 sq.ft.	40 sq.ft.	40 sq.ft.	138 sq.ft.	40 sq.ft.
Shade area/steer	No shade	24	No shade	24	24
Avg. Init. Wt.	618 lb.	618 lb.	618 lb.	618 lb.	618 lb.
Avg. Final Wt.	968 lb.	946 lb.	933 lb.	977 lb.	952 lb.
Feed/lb/gain	7.00 lb.	7.38 lb.	7.46 lb.	6.76 lb.	7.92 lb.
ADG	3.13 ^a lb.	2.73 ^b lb.	2.64 ^b lb.	2.01 ^a lb.	2.79 ^b lb.

a,b Differences significant ($P < 0.01$) if comparable means do not have a common superscript.

concrete or dirt pens. These results were for the summer and may not be true during wet weather. The wetness of the dirt pen may have provided some cooling effect for the dirt animals since, normally, the condition of the dirt pen with 40 ft.² would seem to add to the problems of the animal movement. The results from pens 11 and 12 show there was a significant benefit to animal gains from the large space allotment in dirt pens. What this really means is that 40 ft.² per animal is too little space under the summer conditions of this test. There may be some area in between the two used that would be equally as good as the 138 ft.². Comparison of pens 3 and 10 shows the disadvantage to gains of small area per animal over concrete. These animals had no shade. Again, it may not require anything like the 265 ft.² per animal that was used, but it is obvious that 40 ft.² was too little for the summer conditions of this test. Comparison of pens 9 and 10 show, as in past tests, that there is no advantage for shade in an area with weather like that at Davis.

Space requirements for beef cattle on concrete floors (sloping floors) were studied at El Centro. Pens of equal size had different numbers of animals. One test was started on October 5, 1966, with heifers averaging about 680 lb. each; and concluded December 28. A second test was conducted beginning February 1, 1967. The results are summarized below:

² Ft /Animal	20	40	60	Dirt (125)
Animals/pen	12	6	4	6
Av. daily gain, lb.				
1st Test	2.46	2.74	3.29	2.93
2nd Test	2.00	2.44	2.46	2.54
Mean	2.23	2.59	2.88	2.74

The data have not yet been analyzed statistically, nor is the feed conversion data available to us at this time. It seems apparent, however, that 20ft.² is not enough and there may be differences between the 40 and 60ft.² pens.

Three trials with beef cattle were conducted on a ranch at Firebaugh, California, in an effort to find a system that would relieve the winter mud problems on feedlots. Two trials were for 60 days and one was for 30 days, covering the period from April 1966 to February 1967. The floor treatments were: (a) sawdust on straw bedding, (b) straw bedding in loafing free stalls 3'x7', (c) slatted wood floor with 1-inch spacing, (d) concrete floor, and (e) standard dirt feedlot. All of the first four pens had a shade over the whole pen and a 9-ft. wide washway in front of the feed bunk. In the first trial there were 40 steers per pen, 20 in the second trial and 16 in the third trial. In the first trial, during summer months, gains in the stall pen and the concrete pen were significantly lower ($P < .01$) than all others. Gains were highest in the natural feedlot pen. Differences were small in the second trial (only 30 days and not statistically treated). During the winter trial the gains in the stall pens were significantly less ($P < .01$) than in all other pens. In comparing the two summer trials, the gains with 25 ft.² per animal were less than with 50 ft.². Stalls were used 46.5% during the day (6 A.M. - 6 P.M.) and 67.3% during the night. Stalls for beef cattle, at least as they were used here, are not the answer. More work and analysis will need to be done to determine if the other floor treatments are practical.

Use of stalls for beef cattle during winter was studied at Davis. Sixteen Holstein steers in concrete lots (400 ft.²/steer) had stalls available (under shelter) and a similar number had no stalls. The same treatments were given Hereford steers. An additional group of Herefords were in a muddy pen (kept muddy by watering) with no shelter. The cattle were on test for 178 days. Stalls did not improve rate of gain or feed efficiency. Mud, however, had a drastic effect--daily gain was reduced 27% and feed efficiency was reduced 23%. Stalls were in use 32.6% of the time during the day (6 A.M. - 6 P.M.) and 49.3% during the night. In 1440 observations (10 minute intervals) stalls were in use 100% only once, 89% only 21 times, 78% only 48 times and 67% 129 times. If stalls are used it is only necessary to provide stalls equal to 75% of the number of animals.

2. Hot, Humid Climates Inactive during reporting period.

3. Plan Development. No plans for beef cattle structures were developed during the reporting year.

C. Swine Engineering

Swine environmental studies were conducted at Davis, California, in cooperation with the Animal Science and Agricultural Engineering Departments of the California Agricultural Experiment Station.

1. Effect of Humidity on Swine. Humidity tests started in 1963 were continued. Two tests were completed with pigs at air temperatures corresponding to maximum gain temperatures (MGT) plus 10°F. Six tests have now been completed, three at MGT and three at MGT + 10°F. In the two tests this year pigs were raised from 85 lb to market weight at MGT + 10°F and either 30, 60 or 90% RH, nine Durocs per test, three pigs at each condition during each test. The results are summarized below for both tests. The difference in gains between the high and low humidity was highly significant ($P < 0.01$). Feed efficiency was about the same. There were no significant differences in skin or rectal temperatures for either test.

Relative humidity, %	30	60	90
No. of pigs	9	9	8
ADG, lb/pig	1.28	1.17	1.08
Feed consumed, lb.	4.46	4.00	3.90
Lb. feed/lb gain	3.50	3.53	3.65
Rectal temp. °F	103.9	104.3	104.3
Skin temp. °F	95.0	94.5	95.2

2. Sprinkling of Swine The effects of sprinklers on skin and rectal temperatures, respiration and pulse rates were studied in a series of 18 tests under various conditions. The data have been only partially analyzed and will be reported later.

3. Swine Exercise. Two pens of Duroc gilts averaging 112 lb. each to start were housed in the barn at Davis, with concrete floors. The pigs in one pen were exercised at 9 A.M. and 4 P.M. by walking twice the length of a concrete alley about 300 ft. in length (about 22 minutes per day). The exercised pigs gained at a significantly lower rate ($P < .05$) than non-exercised pigs. Feed required per pound of gain was not different.

4. Nutrition and Environment of Swine. Twenty six pigs (3 litters) were weaned at two weeks of age and fed a semi-purified diet containing a low level of vitamin A for 4 weeks. The pigs were then separated according to litter, sex and weight. Five pigs were killed and liver samples were taken for vitamin A analysis. Five pigs were allotted to each of the following treatments:

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- a) Temp. 75°F, 400 IU vitamin A/lb feed
 - b) Temp. 105°F, 400 IU vitamin A/lb feed
 - c) Temp. 105°F, 1600 IU vitamin A/lb feed
-

There were no differences in rate of gain during the first five weeks. After five weeks, the pigs housed at 75°F gained significantly ($P < 0.01$)

faster than pigs housed at 105°F regardless of the vitamin A content. Increasing vitamin A content of the diet did not improve the rate of gain of pigs housed at 105°F. Temperature did not appear to affect feed utilization as measured by the amount of feed required per unit of gain. The average rectal temperature of pigs housed at 75°F was significantly ($P < .05$) lower than for pigs housed at 105°F (103.9F vs 104.8F and 104.5F). Increasing vitamin A content of the diet increases the vitamin A storage in the liver. There was no difference in liver storage of vitamin A between pigs fed 400 IU per lb. feed and housed at 75°F or 105°F. This trial will be repeated later after the next humidity test.

5. Music for Pigs. Sixty Duroc pigs averaging 77 lb. were assigned to 22'x8' outside pens with concrete floors. Shades over the pens were of corrugated steel. A radio was situated so that pigs in two of the pens would hear it but pigs in the other two could not. The radio was tuned to a station that was on the air 24 hours a day and primary programming was music. Behavior was observed every half hour between 8:30 A.M. and 4:30 P.M. every Tuesday and Thursday for 3 weeks. The numbers of pigs eating, resting, and standing (but not eating) were counted. The trial was conducted for 11 weeks during July and August, 1966. Playing radio music did not affect behavior or performance of the pigs. The lack of response to music in the present trial does not preclude the possibility that situations exist where music is beneficial. Some producers feel that music helps prevent startling of pigs by visitors or sudden noises. At the University hog barn this benefit would be minimal because the pigs are used to the many visitors to the hog barn. Music did not have any effect on the feeding patterns. The periods when the greatest number of pigs were observed eating were 10:30 - 11 A.M. and 1 - 2 P.M.

6. Plan Development. At Beltsville, Maryland, in cooperation with the Southern Regional Plan Exchange, Plan No. 5992, "Farrowing and Growing Building," based on a Virginia plan, but modified and developed, was published by the Cooperative Farm Building Plan Exchange for distribution nationwide.

D. Poultry Engineering

Poultry house environmental design criteria were investigated in controlled laboratory studies at Beltsville, Maryland, in cooperation with AHRD. The criteria were field tested in poultry houses in cooperation with the West Virginia Agricultural Experiment Station at Wardensville. Environmental influences on health and housing were investigated in laboratories at Athens, Georgia, and State College, Mississippi, in cooperation with AH, ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minnesota, in cooperation with the Minnesota Agricultural Experiment Station, the importance of environmental stress in relation to turkey diseases and growth was investigated.

1. Calorimeter Studies at Beltsville. Heat and moisture and other biological data necessary for designing broiler house insulation and its ventilating systems were developed in the calorimeter at Beltsville and successfully applied to two experimental broiler houses in West Virginia. The field studies were made in pens containing 1200 to 5000 growing broilers. In 6 week-long tests analyzed, the amount of ventilated moisture agreed to within 90% of the moisture removal as calculated by using the Beltsville broiler data. A seventh test, of 3-day duration, for chicks 1 to 4 days of age showed ventilated moisture 49% greater than the calculated figure. The calculated moisture removal of the six tests ranged from 16 to 66 lbs/hr. and involved broilers 7 to 60 days of age. The sum of total heat ventilated and lost through building conduction of the six week-long tests was 1.5% to 15% short of calculated figures. The greater disagreement occurred for a group of 5000 broilers 42 to 49 days of age. One other result with 1200 broilers 56 to 63 days showed 12% greater heat output than the calculated figure. These total heat comparisons involved calculated heat of 13,000 to 175,000 Btu/hr.

Field studies involving accurate measurement of ventilation and hygrometric data are difficult to establish with wind, solar and barometric pressure variables. Additionally, when broilers were 35 days of age and older, it was difficult to obtain "representative" litter samples from litter with variable moisture content and thickness. Despite these problems, the Beltsville broiler data can be applied to broiler houses and obtain ventilated heat and moisture outputs to come within 10 to 15% of the calculated figures.

2. Southeast Poultry Research Laboratory. The primary engineering activity at this laboratory was still concerned with development and procurement of specialized equipment and instrumentation necessary for studies with diseased poultry. An additional environmental cabinet (making a total of 5) was completed and installed with control panel, in one of the climatic chamber buildings along with the four other cabinets previously completed. Completion of this work provides a versatile environmental cabinet facility for poultry disease research where, under protective conditions, air temperatures and humidities, enclosure temperatures, ventilation and air circulation rates and air quality may be programmed or varied as desired.

A second type of environmental cabinet of somewhat simpler design and construction than those referred to above was constructed, tested without controls, and modified to meet specified requirements.

3. South Central Poultry Research Laboratory. Engineering research was continued in studies of the effects of construction, equipment and management of poultry housing structures on broiler diseases and condemnations, in cooperation with AH and the Mississippi Agricultural Experiment Station.

A warmer winter temperature and a lower summer radiant heat load can be maintained in broiler houses that are insulated. Very little decrease in condemnation resulted from growing broilers in insulated houses but there was a better feed conversion. An expandable brooder-broiler house was developed that gave satisfactory performance. This type house gave a 30% saving in fuel over the regular insulated house during the winter period.

Chicks brooded at weekly temperatures of 1st week - 85°F, 2nd week - 80°F, 3rd. week - 70°F, and 4th week - 60°F, had as good body weight and feed conversion at the end of the 4th week as chicks brooded at a weekly temperature of 1st. -95°F, 2nd - 90°F, 3rd - 80°F, and 4th- 70°F. Chicks grown out under a fluctuating diurnal temperature between 40° - 80°F and those grown under a constant 60°F had approximately the same rate of body gain, feed conversion, and mortality. Condemnation was slightly higher for the birds grown under the fluctuating temperature. The rates of air exchange between 0.5 and 3.0 cfm/bird had little effect on the condemnation and performance of broilers. The chicks grown in the lower ventilating rates tended to have the lower body weight.

Amount of air passage through woven plastic curtain material varied with pressure differential as well as the method of manufacture of the material. The amount of air passage could be critical for broilers with outside high wind velocities and low temperatures. Under the temperature conditions studied, very little water vapor was transmitted through 15# felt paper or the lap joints.

4. Influence of Turkey Housing Environment on Disease. The influence of housing and environmental stress on incidence of turkey diseases was investigated at St. Paul, Minnesota. Three experiments were conducted with turkey fryer roasters. One objective of the experiments was to determine the possibility of eliminating the N strain of mycoplasma by dipping the eggs in an antibiotic. Two of the flocks remained negative to the disease throughout the experiment. The poults were reared in two pens having different environmental conditions. The South pen has a concrete floor, supplemental heat, and a horizontal ceiling. Birds in this pen continued to have a slight edge over those in the North pen, which is similar to turkey houses used commercially.

Removal of litter moisture by means of vapor pressure differences looks promising as does brooding with electric radiant energy sources supplemented with hot water perimeter heating. Designs of turkey facilities to study the environmental aspects of Bluecomb and Salmonella in turkeys are under way.

5. Eggshell Strength. During the past year a quick, non-destructive method of measuring eggshell strength was developed. It is expected to decrease the \$25 million annual loss in broken eggs. The method utilizes a weak source of radioactivity, whose radiation is reflected or back-

scattered by the eggshell. This backscattered energy is received for 5 seconds by a Geiger-Mueller tube which actuates a counter. The counter reading is not thickness, but a strength index based on density and thickness. This equipment might be used by hatchers to eliminate weak-shell laying strains, by shippers to eliminate weak-shelled eggs, and by designers of egg-handling equipment who need shells of known strength.

6. Plan Development. At Beltsville, Maryland, in cooperation with the Northeastern Regional Plan Exchange subcommittee on poultry, Plan No. 6000, "Poultry House-Floor Management," originally designed by Connecticut, was included in the Cooperative Plan Exchange and released for national distribution.

The same committee approved Plan No. 6001, "Poultry House-Cage Management," designed by Connecticut and distributed nationwide.

E. Extracorporeal Irradiation of Farm Animal Blood.

1. Development of Apparatus. A simulated blood circulatory system consisting of plastic tubing and a pump (heart) has been designed for use in studies on extracorporeal irradiation of blood to be conducted at the National Animal Disease Laboratory, Ames, Iowa. An irradiator for use in the studies is being developed by the Oak Ridge National Laboratory, AEC.

F. Radiosity Studies.

Radiant fluxes from the sky, ground, and surroundings are being measured at Davis and other points in California and at Columbia, Missouri, in order to evaluate the radiant environment of livestock.

1. Radiation Under Poultry Brooders. Last year an investigation was made of the use of ping pong balls as black globe thermometers to measure radiant heat loads. These were used to investigate the radiant heat loads under typical poultry brooders. One brooder was a floor model Lyons Electric brooder 56 inches in diameter. Ten globe thermometers were spaced on 6-inch centers on a diametral line 1-1/2 inches above the floor. At a second location, 6-sided gas brooders were used (Big Dutchman) on a raised, stretched-wire floor. Globes were placed at various locations over the brooder floor to represent chicks at various locations. Day-old chicks were put into two of the four quadrants under this brooder and their activity was recorded with cameras.

Radiant heat loads varied from 147 Btu/hr ft.² at one edge to 165 Btu/hr ft.² at the middle. Such variations were common and, perhaps, the variation is good. At least a chick has some choice in environment. The point of concern is the variation during the day. For example, the globe temperature varied from 98.5°F when the outside air temperature was 68°F

to 79°F when the air was 42°F. There seems to be a need for improvement of controls for such brooders. These tests will be continued.

G. Reducing Pesticide Residues in Animal Products.

1. Automatic Sprayers. Emphasis during 1966 has been on the ultra-low volume (ULV) application of insecticide to cattle, in cooperation with ENT. The results of laboratory tests, field studies, and insecticide residue in milk studies indicate that the ULV technique has considerable potential as a means of reducing the hazards associated with chemical control of livestock insects. In laboratory tests it was found that the application of Ciodrin^R, Malathion, Sevin^R, or GC-4072 at a rate of 1 ml twice daily in concentrations of 0.5% to 1% is capable of protecting cattle from the horn fly.

ULV automatic sprayers performed satisfactorily under field testing despite problems due to incompatibility of the insecticide solvent and valve seal material. Two of these sprayers operating at 150- and 300-cow dairies gave essentially complete horn fly control for the five month test period. The results of these tests indicate that 1% Ciodrin in xylene applied at a rate of 1 ml twice daily is sufficient for controlling the horn fly on dairy cattle.

A study was conducted to determine the potential of the ULV techniques in reducing insecticide residues in milk. No Malathion residue was detected in milk samples taken from 2 dairy cows sprayed with 1 ml twice daily for 21 consecutive days with 2% and 5% Malathion in xylene. Ronnel applied in like manner at concentrations of 5% and 10% resulted in residue in the milk beginning with the first day's spraying. There was a continuous buildup of ronnel in the milk through the 28 treatment days.

A study of the spray distribution on cattle resulting from treatment with the ULV sprayer indicated a much improved distribution pattern over that obtained with the previous 1 ml pneumatic atomizing sprayer. Although the application is made in a one foot wide band from the wither to the loin on only one side of the animal, at the end of seven consecutive treatment days it was observed that insecticide had been translocated to nearly all parts of the animal. Attempts to quantify the photographic records used for the distribution study have been encouraging.

2. Significance of Hair Loss. A study to determine the significance of hair loss as a factor contributing to insecticide loss has yielded data indicating the seasonal cyclic patterns of hair growth and loss on a cow for a complete year. Hair loss during the early summer reached a peak of 0.89% per day of the total quantity of hair on the cow. Such a loss could account for an equal percentage loss of insecticide from cattle during this season.

3. Fly Flight Activity Patterns. Modifications and improvements were made on the system for detecting the flight activity of biting flies affecting livestock. Progress was not as anticipated for the year due to problems with humidity control in the system. The results of preliminary tests hint that there may be a repeating rhythm in the activity of the stable fly. Studies dealing with the feeding activity of horn flies and stable flies were initiated. This work is in cooperation with Projects ENT-h2-1 and ENT-h2-23.

4. Southwestern Veterinary Toxicology and Livestock Insects Research Laboratory. Facilities for the engineering research program that will apply engineering and physical sciences to obtain basic data on biophysical instrumentation and environmental effects for use in studies of animal and insect toxicology and biophysical responses of organisms to chemicals and in the planning stage.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA NO. 10. CONSTRUCTION STANDARDS, WATER SUPPLY, WASTES
DISPOSAL, AND FARMSTEAD PLANNING

Problem. Farm buildings inventoried at \$28 billion in the United States are the production, storage (and sometimes the processing) centers of food and fiber for the nation. Annual cost of repair, remodeling and new construction of the farm plant amounts to \$2 billion, an expenditure that may wastefully use materials through lack of sufficient knowledge of the loadings to which buildings are subjected--the pressures of soil movement, wind gusts, snowfalls, and stored product loads.

Construction may be wasteful because we lack knowledge of design methods for inherently strong shapes such as hyperbolic paraboloids. Our knowledge of materials and materials fastening is incomplete and often inaccurately used in special applications encountered in livestock production.

Product application research stimulates the economy of manufacturers of building products (lumber, steel, cement, plastics, asphalts, aluminum, inorganics), building fabricators, farm producers and the general consumer. Research is needed on loads imposed on buildings by nature; properties of materials for strength, weathering, aesthetics and durability; and the proper combination of materials of construction for the most economical and effective structures.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms, where the hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

Recent action programs involving recreational facilities in rural areas need to be supported with plans for sound, workable structures and other facilities such as cabins, boat landings, shelters, etc. There is also need for plans for roadside stands and similar farm marketing structures in support of rural area development programs.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" and under-sized distribution system are less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection to guard against water-borne diseases such as typhoid, dysentery, other gastro-intestinal disorders and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Pesticide chemicals occasionally show up in farmstead water systems. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally manures and sewage--is becoming more and more of a problem on the modern farmstead. The cattle, hogs, horses, sheep, and poultry on farms and in feedlots in the United States produce more than 2 billion tons of manure annually. The problem is particularly acute with respect to confinement-type livestock operations on the fringes of metropolitan areas--where the total amount of manure is concentrated in the confinement area, odors and dusts are generated and land areas for disposal are remote. Under these conditions, it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means that need to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chores. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. The program is cooperative with selected State Agricultural Experiment Stations and other appropriate agencies.

A. Meteorological. Factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.) are studied at Beltsville, Maryland and selected field locations.

B. Construction Standards. Such as serviceability and safety, for design of farm buildings are studied at Beltsville, Maryland, and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, United States of America Standards Institute, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.

C. Materials and Construction Methods, and development of designs for farm buildings are studied at Beltsville, Maryland.

D. Water Supply and Wastes Disposal for the farmstead are studied at Beltsville, Maryland, College Park, Maryland, in cooperation with the Maryland Agricultural Experiment Station, and Watkinsville, Georgia. Liaison is maintained with SWC (ARS) the Public Health Service, the Water Systems Council, the American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.

E. Farmstead Planning studies are made at Beltsville, Maryland, at St. Paul, Minnesota, in cooperation with the Minnesota Agricultural Experiment Station, and at Davis, California, in cooperation with the California Agricultural Experiment Station.

F. Fallout Protection work for the farmstead is conducted at Beltsville, Maryland, and selected field locations. Liaison is maintained with the Office of Civil Defense, Department of Defense, and other appropriate agencies.

The Federal effort in this research area totals 8.7 scientific man-years. Of this number 0.9 is devoted to meteorological factors; 0.4 to construction standards; 1.6 to materials and construction methods; 4.0 to water supply and wastes disposal; 1.1 to farmstead planning; 0.0 to fallout protection; and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is confined largely to basic and applied studies of structural components for farm buildings; techniques and systems for adequate and safe water supply; and improved methods for economical and sanitary disposal of organic wastes on the modern farmstead.

Representative of the investigations currently in progress in the farm buildings field are those which are concerned with analysis, design and

testing of rigidly connected frames and panels; studies of single cover stressed skin designs for clear span roofs; development of wall and roof designs to resist storm damage; tests of the structural stability of farm buildings under accelerated cycles of loading and adaptations of new construction techniques to problems of farm service buildings and animal shelters.

In the water supply area research is underway to develop ways to economically filter and treat surface waters in order to provide an adequate and sanitary quantity of water for the farmstead operations. Studies are also being made on the problems concerned with demineralizing deeper ground waters.

A widespread research effort is in progress which is attempting to investigate all of the factors involved in the complicated problems concerned with disposal of farm waste materials, particularly concentrated manures resulting from confinement-type livestock operations. The problem is most acute and the public is demanding a fast solution to this unsanitary and potentially dangerous health hazard.

Much of the work in this area is cooperative with the Department.

A total of 47.6 scientific man-years of effort are devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Meteorological Factors

1. Dynamic wind pressures. At Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, dynamic wind pressures are being measured on a full scale test structure that can be quickly rotated to present different exposures to the wind. Instrumentation has been perfected to accurately record pressures and pressure changes that occur in one one-hundredth of a second. Data substantiate the dynamic action of natural wind on the structure and show differences from smooth air flows in wind tunnels. These variations appear to be significant to structural design but must be analyzed to determine the significant frequencies in the resulting wind loads.
2. Sonic boom pressures. In cooperation with the FAA, USAF, NASA, and several contractors, AE participated in a study of sonic boom pressures conducted at the Edwards Air Force Base test site near Lancaster, California. LE&FS participation was to obtain basic data on structural responses of farm structures to sonic booms -- within the concept of diaphragm action of wall and roof surfaces. Data were obtained on the magnitude of loads due to differential air pressure across walls and on the reaction of simple nailed

joints subject to both static load and to boom pressures (positive and negative). Specially designed test panels and instrumented test houses were subjected to the boom from a variety of overflights under a variety of atmospheric conditions and the pressures recorded for analysis and correlation with overflights. Results indicate structural damage due to booms having the normal magnitude and duration of force expected for usual and projected aircraft is highly improbable. The forces involved are small and short-lived in comparison with accepted engineering loadings for service building design. There appears to be no additive effect of wind and sonic loads since the two do not have similar harmonic characteristics.

B. Construction Standards

At Beltsville, Maryland, in cooperation with the American Society of Agricultural Engineers, the United States of America Standards Institute, the National Safety Council, and the National Fire Protection Association, work continues on reviewing, proposing, and acting as consultants of those engaged in preparing standards for the safe erection and use of structures.

Current work with ASAE points toward the compilation of standards on fire safety in farm building design and construction.

C. Materials and Construction Methods

1. Doubly-ruled shell structural systems. Definitive formulae for the placement of edge member intercepts that locate elemental straight line rulings within the surface of hyperbolic hyperboloids (HH) were developed. These permit an architect to execute the working drawings for a surface with any desired sag-to-hump ratio rather than the sag-to-hump ratio of one, the limitation of a hyperbolic paraboloid (HP). Space between intercepts is a geometric progression, controlled by the parameters of sag-to-hump ratio and the number of elemental rulings desired.

Strips of 22-gage narrow rib steel roof decking, 26 inches wide and 20 feet long, formed an excellent diaphragm, easy to fabricate by the lapbolt process for picnic shelter shells. The steel decking, when used on conventional roofs, will span 6 feet, 8 inches, when loaded with 30 pounds per square foot. On the HP, the steel decking spans 20 feet. Although not yet tested for load bearing, it is judged adequate for loads of at least 30 pounds per square foot, when compared to shells that have been tested. A method was developed for precutting the strips by calculation to avoid the "cut and try" method previously used.

2. Plan development. At Beltsville, Maryland, the Cooperative Farm Building Plan Exchange has continued to work with the Regional Plan Exchange Committees on developing plans for recreational and miscellaneous structures. Working drawings were developed and made available as follows:

Plan No. 5998, "Adirondack-Type Shelter," designed by Massachusetts for their recreational program and adopted for national distribution.

Plan No. 5999, "Portable Dipping Vat for Sheep," developed in cooperation with the Animal Health Division, ARS.

Plan No. 6002, "24' Pole Frame Cabin," a 24'x24', one bedroom structure designed by Massachusetts as a comfortable and economical vacation retreat or "luxury" camp.

Plan No. 6003, "24' A-Frame Cabin," a 24'x24', loft type cabin adopted from a Massachusetts design for recreational use in the mountains or at a beach. Can be built on a "self-help" basis by a person with reasonable ability with tools.

Plan No. 6004, "16'x20' Cabin," adopted from a Massachusetts design for those of limited finances, time, and construction skills. Can also serve as an auxiliary structure such as concession stand or storage shelter.

Plan No. 6005, "Split Ring Trusses," original design by Pennsylvania developed and issued for national distribution.

Plan No. 6006, "Tilting Squeeze for Sheep," designed by Oregon, slightly modified for adoption in the Plan Exchange.

Plan No. 6007, "40' Nailed Truss;" Plan No. 6008, "48' Nailed Truss"; and Plan No. 6009, "50' Nailed Truss;" all originally designed by Massachusetts slightly modified for adoption in the Plan Exchange.

D. Water Supply and Wastes Disposal

1. Farmstead and rural water systems. Studies on farmstead and rural water supply systems design criteria are continuing in Maryland in cooperation with the Maryland Station and selected farmers. Water use data were collected at three additional farms during the year, using a portable intermediate storage water system at two of them where demand exceeded source yield for two hours. At the third farm a large 23,000 gallon intermediate storage system was already installed. All data collected conformed closely with previously determined demand-duration data. Declining ground water yields due to extended drought further proved the value of intermediate storage systems. A study was made of minimum well construction standards and frost heave to help eliminate differences in USPHS requirements for well construction affecting dairymen producing milk for interstate shipment. Considerable time was devoted to developing a revision of the water supply plumbing design appendix for the National Plumbing Code. The design recommendations are being changed to a system of velocity limits based on water quality and limiting noise and water hammer. A simplified method was developed for estimating peak water demand rates in the home using the data collected and an analysis procedure.

developed by the NBS.

2. Pesticide pollution of farmstead water supplies. Work on this project was initiated in 1965 at Beltsville, Maryland, and Watkinsville, Georgia, to develop information on means by which pesticides reach farmstead water supplies, means for preventing entry, and means for dealing effectively with those that do enter. Regular examination, sampling and analysis of 48 farmstead water supply systems in two Maryland counties is in progress. All selected wells have been sampled at least twice. Five of the 24 in the Hagerstown Valley of Washington County (limestone area) show confirmed low-level concentrations of chlorinated hydrocarbon pesticides -- all less than one part per billion. Only one well of the 24 sampled in Wicomico County, on the coastal plain, shows confirmed pesticide content -- 0.2 parts per billion. Limited preliminary work on pesticide removal indicates that active carbon filters show promise as a practical means of removing some types of pesticides from farm water supplies. At Watkinsville, Georgia major effort was devoted to completing and equipping a laboratory building in which to develop and evaluate methods and equipment for removing pesticide pollutants from water. Laboratory methods were studied to determine best procedures to use for the particular requirements of this work. An experimental water system was constructed for use in studying means of pesticide removal. Activated charcoal filters have been constructed and are undergoing preliminary tests. A contaminated well discovered in Southeast Georgia is now being observed. Preliminary findings indicate that a period of continuous pumping does not lower the pesticide level in the water.

3. Farm animal wastes disposal. Laboratory and field studies are continuing in Maryland, in cooperation with the Maryland Station and selected farmers. An outdoor hydroponic bed was installed to field check earlier laboratory findings that hydroponic techniques could be employed to remove plant nutrients (N,K,P) and trace minerals from manure lagoon effluents and thus avoid "feeding" algae and other undesirable aquatic growths in receiving waters. Observations to date indicate the bed will satisfactorily extract the nutrients and provide a good stand of grass that can be harvested for feed. Analyses and evaluation over a growing season have not yet been made. Observations over the winter and early spring showed continuous extraction of copper and other trace minerals and good early growth recovery of perennial grasses. Work on air filtration in an effort to control odors in poultry houses showed a relationship between poultry house dust and persistence of odors. Dust picked up on a ventilating fan filter pad retained a noticeable "poultry" odor for more than 6 weeks, while air passing out through the pad carried a noticeable ammonia odor.

An engineering feasibility and cost analysis of elements deemed to have most promise of successful incorporation into commercial enterprises for poultry manure disposal and associated odor control was initiated under Cooperative Agreement dated January 31, 1967, with the Agricultural Experiment Station of Cornell University. No reportable progress to the end of the reporting period.

4. Rural community sewage disposal. A PL-480 project to reduce costs involved in treatment and disposal of sewage from small rural communities through determination and application of optimum algal-protozoal and algal-bacterial symbiotic balances was continued at the Maharaja Sayajirao University, Baroda, India.

Study of the biochemical changes taking place in the soluble constituents of sewage in oxidation ponds showed that percentage reductions of the three important factors BOD, Am-N, and PO_4 are greater in the bacterial (initial) phase than in the algal (later) phase. Coliform group density (MPN per 100ml) showed more than 99% reduction in 42 days.

Zoogloea isolated from the viscous slime and scum in raw sewage showed characteristics resembling those from activated sludge and trickling filter eco-systems--indicating they could be tentatively classed as zoogloea ramigera and tending to confirm the existence in nature of strains of zoogloea ramigera that are physically and/or biochemically different. Formation of the viscous scum occurred within 24 hours at 37°C, in 24-48 hours at 28-30°C, and after a week at 20°C.

Field study of sewage purification in 8 oxidation ponds operating in series (first four facultative, last four aerobic) showed greater % reductions of BOD, Am-N, and PO_4 in the effluent from the first pond and that the % reductions generally decreased with the increase in pond number. All reductions were considered satisfactory. Final effluent was found bacteriologically satisfactory.

E. Farmstead Planning.

1. Farmstead model layout studies. Studies in cooperation with the Minnesota Experiment Station on the use of scale models for analyzing farmstead layout problems were completed and a report prepared for publication. The work demonstrated that scale models can prove valuable aids in farmstead planning, but need to be supplemented by some numerical analysis.

2. Chore time standards At the Minnesota Experiment Station a usage study of a free-stall, slat-floor, dairy housing system, both insulated and uninsulated, with outside feeding, showed that in cold weather the animals stayed in the stalls at night from dusk to dawn, and during the daylight hours on those days when it was snowing and/or windy. In the summer and fall they used the stalls in the afternoon to escape the heat, but usually remained outside at night. Approximately one-third of the manure was dropped inside and could be pumped from the pits as a liquid about eight months of the year. In the coldest four months, the manure in the pits and on the slats was frozen so that it had to be scraped from the slats and handled as a solid. In the winter it was necessary to clean manure droppings from 60 to 70% of the stalls each day. In the summer, this

problem was not as great, as the animals spent more time standing on the slatted-floor alley than in the free-stalls . The use of heat lamps in the insulated unit to induce the animals to spend more time inside on sub-freezing days was not effective in keeping the manure on and under the slats from freezing. Observations of the equipment arrangement in the outside feeding area indicated that the location of the waterers, silage, and hay bunks had no apparent effect on the amount of time the animals spent inside the housing units.

3. Animal response to sonic boom. In cooperation with AH and Biometrical Services Staff, AE participated in a study supported by the National Sonic Boom Program, USAF, and the NAS to determine the effects of the sonic boom on mink production. Work during the reporting period consisted of preliminary planning, site selection, review of technical literature and adaptation of a sonic boom simulating device.

F. Fallout Protection

No reportable progress during reporting period.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Materials and Construction Methods

Liu, Robert C., and Teter, Norman C. 1967. Hyperbolic Paraboloid Shells Built with Wood Products. IASS Bul. 29. March

Agricultural Engineering Research Division. 1966. Display Stands for Farm Produce. (Exchange Plan No. 5982). Miscellaneous Publication No. 1017. May

Agricultural Engineering Research Division. 1966. Storage Shed for Fertilizer, 40 Ton Capacity. (Exchange Plan No. 5966) Miscellaneous Publication No. 1021. July.

Agricultural Engineering Research Division. 1966. Boat Landing. (Exchange Plan No. 5975) Miscellaneous Publication No. 1022. August.

Agricultural Engineering Research Division. 1966. Circular Concrete Manure Tank (Exchange Plan No. 5984). Miscellaneous Publication No. 1023. July.

Agricultural Engineering Research Division. 1966. Potato Storage, 60,000 cwt, Door-Per-Bin. (Exchange Plan No. 5979) Miscellaneous Publication No. 1024. July.

- Agricultural Engineering Research Division. 1966. Irrigation Pipe Trailer. (Exchange Plan No. 5942). Miscellaneous Publication No. 1025 June.
- Agricultural Engineering Research Division. 1966. Saddle Horse Barn. (Exchange Plan No. 5994). Miscellaneous Publication No. 1029. August.
- Agricultural Engineering Research Division. 1966. Roadside Stand (Exchange Plan No. 5983) Miscellaneous Publication No. 1032. September.
- Agricultural Engineering Research Division. 1966. Calf Barn, Open Front, Pen Type. (Exchange Plan No. 5970). Miscellaneous Publication No. 1033 November.
- Agricultural Engineering Research Division. 1966. Cattle Dipping Vat and Inspection Facility. (Exchange Plan No. 5940) Miscellaneous Publication No. 1035. September
- Agricultural Engineering Research Division. 1966. Incinerator...Concrete Block (Exchange Plan No. 5996) Miscellaneous Publication No. 1040 November.
- Agricultural Engineering Research Division. 1966. Portable Calf Pens (Exchange Plan No. 5933) Miscellaneous Publication No. 1043. December.
- Agricultural Engineering Research Division. 1967. Picnic Shelter...Wood Construction. (Exchange Plan No. 5995) Miscellaneous Publication No. 1047 January.
- Agricultural Engineering Research Division. 1967. Cabin, Concrete Masonry Construction. (Exchange Plan No. 5968) Miscellaneous Publication No. 1050. February.
- Agricultural Engineering Research Division. 1967. Vacation House (Exchange Plan No. 5997) Miscellaneous Publication No. 1052 March.

Water Supply and Wastes Disposal

- Eby, H. J. 1966. Evaluating Adaptability of Pasture Grasses to Hydroponic Culture and Their Ability to Act as Chemical Filters. Proceedings National Symposium Management of Farm Animal Wastes. pp. 117-120. May.
- Eby, Harry J. 1966. Two Billion Tons of ---What!-- Compost Science pp. 7-10. Autumn.

AREA NO. 11: ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR
INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since very low tolerances of DDT and other pesticides are permitted in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled by electrical methods and equipment alone or in combination with insecticides, chemosterilants, and biological attractants?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform saturation with increased practicability of once-over harvest programs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eleven States. Electrical and physical methods for cotton insect control are studied in South Carolina, Mississippi, and Texas, with the Texas project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods of tobacco insect control are studied in North Carolina, South Carolina, Kentucky, Virginia, and Saint Croix, Virgin Islands, and fruit and vegetable insect

control and light trap design in California, Arizona, and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska and Tennessee.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A & M University, and others.

Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee, in cooperation with the Departments of Agricultural Engineering, Agronomy, and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 10.6 scientific man-years; of this number 5.8 are devoted to electric traps for insect survey, destruction and control; 0.8 to components and design of electric insect traps for survey and control; 1.0 to physical methods of fly control; 1.0 to sonic and ultrasonic energy for insect control; and 2.0 to radiofrequency treatment of grain and forage seed.

A 2-year contract is in effect with VPI to investigate the possibility of attracting or repelling flies with sound.

PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production.

Investigations in progress, many of which are cooperative with the Department, involved the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics; exploration of the feasibility of using ultrasonics and electric shock to control rats, mice, and birds; studies of the possibilities for a major advancement in the technology of small particle depositions through the application of electrostatic, thermal or other inertial forces; and use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

A total of 2.0 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Insect Survey, Destruction and Control1. Electric Traps for Vegetable Insects

Applications of electric light traps for control of vegetable insect pests were primarily studied at Lafayette, Indiana, Riverside, California, and Red Rock, Arizona.

Activities at Lafayette, Indiana, were cooperative with the Purdue University Agricultural Experiment Station through the Departments of Agricultural Engineering and Entomology, and the Indiana Electric Association continued to give partial financial support for the program. The H. J. Heinz Company, Plymouth, Indiana, and Osborn Seed Service, Burr Oak, Indiana, both commercial producers of cucumbers, cooperated with investigations to determine the effectiveness of electric light traps in controlling striped and spotted cucumber beetles.

The striped, Acalymma vittatum (F.), and the spotted, Diabrotica undecimpunctata howardi Barber, cucumber beetles are the principal insect pests of cucumbers in Indiana, causing damage directly from the time the plants emerge until they die by feeding on the roots, stems, leaves, blossoms, and fruit; and indirectly in inoculating the plants with, and by spreading, the causal organism (Erwinia tracheiphilus) of the bacterial wilt of cucurbits. Prior research on protecting cucumber plants in small vegetable-garden plots conducted from 1958-63 indicated that, use of light traps might reduce the number of insecticide applications required in commercial production.

Experiments to investigate the area range of effectiveness of electric insect traps used with and without a complementary insecticide for protecting cucumbers in large commercial plantings from striped and spotted cucumber beetles were begun in 1966 near Plymouth, Indiana. Effectiveness of treatments (light trap + no insecticide, and light trap + insecticide) at various distances from traps was evaluated through incidence of wilt and through yield. Six traps having five 15-watt blacklight lamps as attractants were used in each of 2 fields. These traps had the lamps mounted over a funnel-fan arrangement that directed the insects down into a barrel containing diesel fuel. Rows of cucumbers were left unsprayed at various distances from the traps and these plants were compared with adjacent sprayed plants.

Plant wilting in plots 460 and 600 feet from the traps was first observed about 3 weeks after the beetles began feeding. In one field, at distances 110 feet or less from traps, the progression of wilt was delayed about 4 weeks. In the other field, at distances 175 feet or less from traps, the progression of wilt was delayed 1 to 2 weeks. In the first field, 13 percent of the plants in plots 11 and 110 feet from the traps were dead from wilt on September 7, while 46 percent at 460 feet were dead. In the other field, 29 percent of the plants in plots 15, 95, and 175 feet were dead from wilt on

September 7, while 32 percent at 600 feet were dead. This substantiated prior findings indicating the effect of traps to be negligible beyond 125 feet. No real yield differences at different distances were observed, although fewer plants were producing cucumbers in the distant plots as the season progressed. Severe drought occurred, so if plants had survived and harvest continued longer, as is normal, differences would probably have become significant. There were no evident differences in incidence of wilt or yield between sprayed and unsprayed plants at any distance.

The responses of the striped and the spotted cucumber beetles to electric traps, as affected by the presence of diesel fuel in the collection chamber and by environmental factors, were investigated. The presence of either diesel fuel or calcium cyanide in collection chambers did not effect the catches of cucumber beetles, but identifying the diesel-soaked insects was very difficult because colors and details were obscure. Studies concerning the responses of cucumber beetles to light traps as related to factors influencing flight showed that peak flight occurred from 9 to 10 p.m. Secondary peaks occurred from 4 to 5 a.m. Temperature was found to be the most important factor influencing collections. Maximum collections were made when air temperatures were between 60° and 75° F. Collections were reduced with higher and lower temperatures. Wind velocity had little effect on the flight of the striped beetle; however, the spotted cucumber beetle had increased flight activity when wind ranged between 6 and 9 knots per hour.

Research at Riverside, California, was continued in cooperation with the University of California and Entomology Research Division (ENT) ARS. The work consisted of testing various preparations of synthetic sex attractant (pheromone) for the cabbage looper, Trichoplusia ni, developing a technique for dispensing the active pheromone; and installation of a large trapping experiment in Arizona.

Several formulations of synthetic pheromone were compared for effectiveness in increasing catches of male cabbage loopers in blacklight insect traps. The formulations were prepared by the Pesticide Chemicals Research Branch, ENT, ARS. The first formulation was used to test various dispensing techniques. Of those methods tried, the best results were obtained by treating 40 grams of sand with 0.1 grams of pheromone. The sand-pheromone mixture was placed in a beaker and attached to the trap. This dispenser increased catches of males for 42 days in the field.

Several trap designs were tested using the pheromone without blacklight. The only trap that was effective was an electrocutor grid and it killed nearly as many as were caught by a blacklight trap.

Based on previous experiments, a large field trapping experiment was initiated on an isolated lettuce ranch near Red Rock, Arizona. Approximately 2400 cultivated acres are being trapped and all traps are equipped with pheromone dispensers and two 15-watt blacklight lamps. The ranch is divided into 80-acre fields which are 1/4 by 1/2 mile, with roads and irrigation canals around

each field. There are approximately 400 traps located at 330-foot intervals along the roads separating the fields. The electrical distribution system was buried underground and required approximately 26 miles of cable. The initial installation cost was approximately \$40 per acre. If the life expectancy of the installation is 10 years, the system should operate for \$7 per acre per year for all costs. The grower presently spends as much as \$100 per acre of crop for chemical control of insects. Evaluation of results will be based upon analysis of collections from approximately 10 percent of the light traps plus egg and larval counts on crops inside and outside the area. Operation began in February 1967. The field experiment at Red Rock will continue, with contributing fundamental research being continued at Riverside.

2. Electric Traps for Cotton Insects

Research on the use of visible and near ultraviolet radiant energy for attracting and collecting or controlling cotton insects was conducted principally at College Station, Texas, with limited studies also conducted at State College, Mississippi.

At College Station, Texas, studies were cooperative with the Departments of Agricultural Engineering and Entomology of the Texas Agricultural Experiment Station and the Entomology Research Division, ARS. This project contributes to Regional Project S-37, "Basic Factors Involved in the Control of the Pink Bollworm". In cooperation with entomologists of Cotton Insects Systemic Chemicals Investigations, ENT, group response techniques and a V-shaped test chamber were used in intensity and spectral response studies with adults of the bollworm, tobacco budworm, and cabbage looper. In general, response of all insect species increased with intensity. Peak response for the bollworm to 365-nanometer stimuli was found to be at an energy level of 200 pico watts/cm², whereas the tobacco budworm and cabbage looper continued to show increased response with increasing intensity throughout the range of intensity levels employed. Spectral response studies with the cabbage looper showed peak response in the near ultraviolet with a secondary peak in the 475- to 525-nanometer region. Future plans include equipment modifications and calibrations to permit spectral response studies in the middle and far regions of the ultraviolet spectrum.

Strontium blue and blacklight fluorescent lamps were compared in experiments designed to yield data for evaluating two methods ("Latin square" and "Covariance") of analyzing insect data from trap and/or lamp comparison tests. The coefficients of variation calculated by each method were nearly identical, indicating equal ability for each method to remove nightly variations due to location and environmental effects. Each method has its particular application. The covariance comparison method fits situations where use of multiple locations and traps are prohibitive and where labor is in short supply. The Latin square comparison method yields valid data in a much shorter time and is to be recommended if adequate equipment, test locations, and labor are available.

A method for determining the efficiency of a particular trap as related to its ability to catch insects attracted was tested. Details and methods of estimating the number of insects attracted to a trap were developed by placing a number of 1-ft.-square pans filled with oil and water on the ground around the test trap. Trap efficiencies of from 50 to 10 percent were calculated for bollworms and from 38 to 8 percent were calculated for cabbage loopers. Trap efficiency determinations by release-recovery techniques will be made in order to verify pan technique determinations.

Traps equipped with 15-watt blacklight lamps and small fans were used at Guemez, Tamps., Mexico, in a cooperative study with Southwestern Cotton Insects Investigations, ENT, Brownsville, Texas, to determine the effectiveness of high density trap installations for reducing bollworm populations. Traps were installed at a density of 1.25 per acre within a somewhat isolated 60-acre area planted to corn and citrus. The desired degree of field isolation was not achieved due to unseasonable rains resulting in the development of adjacent host plants. An estimated total of 10,318 females was removed from the population by the traps during the critical tasseling and silking periods. Evaluation of trap effects as determined by egg and larval counts and release-recovery experiments are inconclusive. Further investigation appears warranted and work will continue in 1967.

At the Boll Weevil Research Laboratory, State College, Mississippi, an experiment was conducted to define sensitive and insensitive parts of the light spectrum for diapause suppression in the boll weevil. One group of weevils was exposed to an 11-hour photoperiod which initiates diapause; a second group was exposed to a 13-hour photoperiod which inhibits diapause. A third group was exposed to an 11-hour fluorescent period followed by 2 hours of illumination with narrow bands of light of different spectral compositions. The region of the light spectrum with the greatest sensitivity in preventing diapause in this insect was found to be between 485-570 mμ.

3. Electric Traps for Tobacco Insects

Research on development and use of electric insect light traps for attracting and controlling tobacco insects was conducted at Blacksburg, Virginia, Oxford, North Carolina, Lexington, Kentucky, Saint Croix, Virgin Islands, Quincy, Florida, and Florence, South Carolina, per a contract with Clemson University. All work is cooperative with the Entomology Research Division and, except for that at Saint Croix, with State agricultural experiment stations.

At Blacksburg, Virginia, electrophysiological studies on the visual sensitivity of the tobacco hornworm moth, Manduca sexta (Johannson), were continued. Most of the observations are based on data obtained from male moths because of a shortage of female pupae. Utilizing the electroretinogram (ERG), the spectral sensitivity of this moth was determined between 340 and 600 nanometer wavelength range. A major sensitivity peak occurs at 550 nanometer in the visible spectrum with minor peaks occurring at approximately 500 and 370

nanometer in the visible and ultraviolet spectrums, respectively. These peaks continue to occur with a tenfold increase in the irradiation level. Findings do not indicate if moths are attracted or repelled at these wavelengths. Moths reared on a carotene deficient diet have responded much less to irradiations between 340 and 600 nanometer than moths from a natural population and have appeared to be practically blind. A study of the eyes of these moths using light and electron microscopes shows damaged structure of many parts. This has not been observed in moths reared on regular diets. ERG studies of male moths caught in sex attractant traps showed patterns similar to those from moths of natural populations. Studies are being conducted to determine the response from nerves serving flight muscles when the eye is irradiated at various wavelengths between 340 and 600 nanometer. Entomological studies of the tobacco hornworm moth have revealed structural evidence of a sound receptor. Sonic analysis will be made.

At Oxford, North Carolina, investigations to determine the effectiveness of insect light traps distributed over large areas to control or reduce tobacco insects continued during 1966 in cooperation with Entomology Research Division. The physical installation and the method of operation was essentially the same as used in the 1965 studies.

Preliminary analysis of the 1966 data indicate trends very similar to those found during prior years of operation except that estimated reductions, in general, were somewhat higher, possibly indicating a yearly accumulative effect of light traps in reducing tobacco insect populations. Calculated reductions for hornworms between 20 and 0 miles from the center of the area were 70 percent for the female tomato, 86 percent for the male tomato, 86 percent for the female tobacco, and 100 percent for the male tobacco hornworms. Calculated reductions, based on field counts in noninsecticide treated tobacco plots, between the above-mentioned distances were 99 percent for hornworm eggs and first instar worms on tobacco and 77 percent for hornworm damage to tobacco plants. Similarly, budworm egg and damage count on untreated tobacco showed calculated reductions of 64 and 43 percent, respectively. As was the case last year, the estimated average number of insecticide applications to tobacco was greater outside than inside the light trap area.

Preliminary data from two farmer-owned, large-area light trap installations in North Carolina indicate a suppression of tobacco insects similar to the Oxford installation when the farmer traps were maintained in good repair.

Results of tests using insect light traps in open areas, edge of wooded areas, and wooded areas, indicate a distribution of about 72 percent, 25 percent, and 3 percent, respectively, for the tobacco hornworms within these areas. Corn earworms captured in these tests indicated a distribution of about 56 percent, 38 percent, and 6 percent, respectively.

Insects captured in light traps spaced at 10-foot intervals on a fire tower indicate a fairly uniform vertical distribution of hornworms from 10 to 90 feet. However, corn earworms appear to be slightly more abundant at the higher levels.

Investigations at Lexington, Kentucky, related to the evaluation of electric insect traps for controlling tobacco insects were continued. The objectives were to determine if an areawide program of electric insect traps with a fairly uniform density of three traps per square mile over a 100-square-mile area would reduce or possibly eliminate the need for chemical applications in controlling hornworms in tobacco and to evaluate the efficiency of experimentally designed insect traps for attracting and catching hornworm moths. This work was cooperative with the Kentucky Agricultural Experiment Station through the Departments of Entomology and Botany, and Agricultural Engineering. Farmers in Shelby County cooperated by purchasing and installing the traps. The method of evaluating degrees of control was by checking the number of hornworm eggs and larvae in one-half acre experimental plots of tobacco. Although the hornworm moth catches had a fairly good regression line from outside to inside and more eggs and larvae were detected outside the area than inside, no definite regression line of eggs and larvae versus distance from the center of the control area was established.

Area control studies were started on Saint Croix. Data have revealed a decrease in light trap catches as the moon increases in brightness and a converse relation as the moon wanes. Wind has a significant influence on insect activity which apparently reduces the trap catches as its intensity increases. Individual light trap catches of specific insects have varied considerably with an erratic fluctuation among traps. These factors will be analyzed as additional personnel become available by transfer to the project.

At Quincy, Florida, fields of shade-grown tobacco receiving an integrated control program consisting of light traps placed around the outside of the field; a pre-plant systemic insecticide treatment; a virus, *Bacillus thuringiensis*, and relatively nonpersistent insecticides received no greater budworm and cabbage looper damage than check fields on which significantly more applications of insecticides were applied. Data obtained from an entomological survey in an area of farmer-operated light traps revealed a 10-20 percent reduction in insecticide applications.

Engineering activity at Florence, South Carolina, involved efforts to determine the condition of farmer-operated light trapping equipment being evaluated by ENT as an area population control measure. The state of repair of traps was found to vary considerably with some units ineffective in retaining insects. Extensive educational and adequate maintenance programs are required to enable light traps to function at full capability.

4. Electric Traps for Turf Insects

An experiment at Lafayette, Indiana, was continued for the second year to investigate the use of blacklight traps for controlling sod webworms in lawns.

Three 15-watt blacklight omnidirectional traps were operated in lawns having known infestations of sod webworms. These traps were used both to indicate the seasonal abundance and to control the pest. A suction trap (with no attractant) was also operated to sample the diurnal activity of 4 species of crambids. Lawns protected by light traps were essentially free from damage. Trapping with suction and blacklight traps will be continued. Insecticide control studies will be made on heavily infested bluegrass lawns.

5. Electric Traps for Fruit and Nut Insects

Cooperation at Yakima, Washington, was continued with ENT, ARS, in preliminary investigations of usefulness of light traps for control of codling moth, Carpocapsa pomonella. Facilities were equipped for active cooperation and a professional scientist reported for duty in April 1967.

At Albany, Georgia, cooperation with ENT, ARS, was also continued on studies of pecan insects, particularly the hickory shuckworm, Laspeyresia caryana (Fitch), the pecan leaf casebearer, Acrobasis juglandis (LeBaron) and the pecan nut casebearer, Acrobasis caryae Grote. An experiment for evaluating the effectiveness of light traps for control of these species has been initiated in an isolated 10-acre pecan grove using approximately three light traps per acre. A professional scientist is being sought for this activity.

B. Components and Design of Electric Insect Traps for Survey and Control

Of several trap design features tested at College Station, Texas, near-ultraviolet output of attractant lamps affected the trap catches more than any other single factor. The number of moths caught was found to be nearly directly proportional to the total near-ultraviolet output of attractant lamps. Traps with emissions ranging from 0.0 to 20,000 milliwatts of near-ultraviolet output were tested. Funnel size was another factor that appeared highly significant, especially as related to catches of insects in general. An increase in funnel diameter resulted in an increase in numbers and/or weight of insects caught. Funnel diameters tested ranged from 14 to 60 inches. A trap spacing experiment using 15-watt blacklight lamps showed that catches increased in almost direct proportion to numbers of traps operated regardless of spacing. Trap spacings of 450, 225, 150, and 112.5 feet were compared. These results indicate optimum spacing for these traps is something less than 112.5 feet. Further investigation will be made of the influence that total near-ultraviolet output has on trap catches, with particular emphasis on determination of maximum effective output per trap. Funnel size studies will also be continued.

At Oxford, North Carolina, traps modified by the addition of red, green, or white baffles or lamps were not, in general, more efficient in capturing insects than those not modified.

In field experiments at Chatham and Blacksburg, Virginia, light traps with fans below the lamps did not catch more hornworm moths than traps without fans. This condition existed in 1965. Again this year, more corn earworm,

Heliothis zea (Boddie); cabbage looper, Trichoplusia ni (Hubner); and armyworm, Pseudaletia unipuncta (Haworth), moths were captured in the traps equipped with fans than in traps without them. A similar trend was indicated in the capture of budworm moths, Heliothis virescens (Fabricius). As found in prior experiments, light trap catches were increased by increasing the number of 15-watt lamps from one to four per trap or by changing from a 15-watt to a 30-watt lamp, but the increased catches were less than directly proportional to the increased lamp wattage. No significant differences were found in catches by traps equipped with new lamps and by those equipped with lamps that had operated for a period equivalent to two seasons.

The research relating to insect trap design was conducted on Kentucky Agricultural Experiment Station farms located near the University campus. Three replications of six different designs were tested. These designs were:

1. A standard one-lamp gravity trap.
2. A one-lamp trap with suction fan rated 450 c.f.m.
3. A three-lamp gravity trap with 3 vanes - center open.
4. A three-lamp gravity trap with 3 vanes - center closed.
5. A four-lamp gravity trap with 4 vanes - center open.
6. A four-lamp gravity trap with 4 vanes - center closed.

The results of operating these traps for 6 weeks showed that the trap with fan had the poorest operating efficiency of all, which had been suspected from last year. The trap with four lamps and an open center rated best of all types and statistically was better at the 5-percent level than all except the trap with four lamps and a closed center.

In Indiana activities concerning the use of insect traps for survey purposes included assisting cooperators throughout the North Central States with general insect surveys and participating in North Central Regional Project No. 67, Migration of Aphids and Noctuids. Cooperative activities with the Plant Pest Control Division (PPC) and the Entomology Research Division (ENT) were also continued. Survey entomologists in the North Central States use light traps to obtain data on the abundance of insects of economic importance. This information is sent to the Cooperative Economic Insect Report for release to interested entomologists and producers. Participation in North Central Regional Project No. 67, Migration of Aphids and Noctuids, was limited to assisting Purdue cooperators with installation and maintenance of trapping equipment for corn earworm migration investigations. The 20 light traps used were located throughout Indiana. Data obtained provided valuable information to extension workers and farmers as to the need for and time to apply chemical controls.

Use of blacklight traps for quarantine surveys for European chafer, Amphimallon majalis (Razoumowsky), and for detection surveys at ports of entry was again expanded by PPC, with additional chafer infestation areas located. Assistance was again provided to the Northeastern Region of PPC concerning equipment problems of the European chafer program and continuing

cooperation was provided ENT on the fundamental European chafer research program at Geneva, New York.

C. Physical Methods for Fly Control

At Beltsville, Maryland, investigations of physical methods for control of flies were continued with cooperation of Entomology, Animal Husbandry, and Agricultural Engineering Research Divisions, ARS.

Studies of the effectiveness of farmstead sanitation in reducing fly populations were continued and confirmed previous findings that significant population reductions (about 1/3) can be achieved by sanitary measures on a single farm when unsanitary farms are as close as 1/2 mile away. Data on re-capture of released marked flies indicated that flies disperse primarily upwind and to "dirty" areas with many possible breeding sites, rather than to "clean" areas. Similar sanitation studies conducted under contract by Louisiana State University on selected farmsteads also indicated reductions in fly population to be directly related to the level of sanitation maintained.

In evaluation trials of existing fly-control devices including electrocutor grids, electrocutor grids plus light attractants, and attractant-toxicant devices (ultraviolet attractant lamps behind a gauze curtain treated with a contact insecticide), all proved virtually ineffective when used outdoors in cattle pens. Numbers of flies killed were insignificant and unlighted grids were as effective as lighted ones, indicating random flight to all units. Three types of attractant-toxicant devices tested inside barns killed slightly larger numbers of flies than when used outdoors.

Further tests of the responses of house flies and face flies to various wavelengths of electromagnetic radiation indicated that type GRO (Gro-Lux) lamps to be more attractive than would be suspected from their appearance to human vision, but less attractive than "blacklight" ultraviolet. When ultraviolet lamps were cycled "on" and "off" for varying proportions of time the numbers of flies collected increased as the "on" cycle lengthened, indicating no benefit from cycling. The response of houseflies in a lighted environment to various attractant wavelengths appeared to be affected by both temperature and sex. At low temperatures (65° F.) the catch is predominantly males and longer wavelengths - green, yellow, and orange - seem more attractive than ultraviolet. At high temperatures (90° F.) the catch is predominantly females and short wavelengths - ultraviolet and 4000 Å blue - seem most attractive. Limited tests with infrared radiation indicated that flies readily detected and followed currents of warm air but were not attracted by direct infrared radiation.

A test of residue accumulation problems from feeding larvicides to dairy cattle was begun in cooperation with the Dairy Husbandry Research Branch. Various larvicides will be used in long-term feeding trials and the residue in milk and animal tissue carefully assayed. Facilities are being expanded to accommodate this work.

D. Sonic and Ultrasonic Energy for Insect Control

At Blacksburg, Virginia, contract research on the responses of house flies and face flies to sonic and ultrasonic frequencies was continued. No significant response showing promise for application as a control measure has been observed from either species with any of the frequency and intensity combinations tested. This work will be continued with a broader scope, using the sound equipment to evaluate responses of other insects than flies and attempting to determine whether sound produces neurological responses in flies not apparent from gross behavior.

A study of the bollworm moth response to ultrasound was conducted in cooperation with entomologists of the Southeastern Cotton Insects Investigations, USDA, Florence, South Carolina. Tests indicated that, of the stimuli used, a frequency of 20 to 30 kilohertz (KHz), a pulse rate of 10 pulses per second, and a pulse duration of 10 milliseconds were the most effective in reducing moth catch. The effective range of the ultrasonic equipment was determined using the cotton bollworm as the detector. The sound produced a good sensory response at a distance of 120 feet using a stimulus of 20 KHz with two 7.8 msec. pulses per second. A detectable response was obtained at a distance of 270 feet.

Ultrasonic equipment was used in a cotton field to study the response of the cotton bollworm moth to ultrasound. The test area was 121 feet wide and 85 feet deep with five speakers spaced equal distances apart and mounted 2 feet above the top of the cotton. The moths rarely entered the airspace over the sound plot, but those that did quickly turned away or dived or spiraled into the cotton foliage. As long as the moths remained below the level of the cotton terminals, a normal activity pattern of ovipositing, mating, and feeding was maintained. When moths attempted to fly above the level of the cotton terminals they entered the sound field and dived back into the foliage. Egg and larval counts remained about the same in the control and ultrasound test plots. More work should be done on speaker location, on flight patterns of the moths, and on the cotton bollworm moth's sensory system.

E. Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

Studies relating to potential uses of radiofrequency (RF) energy for insect control and to the effects of glow-discharge and RF radiation on seed and plant products have been continued.

Investigations were directed toward developing basic information and evaluating possible agricultural applications. The research is cooperative with the Departments of Agricultural Engineering and Entomology at the Nebraska Agricultural Experiment Station, the Departments of Agricultural Engineering and Agronomy at the Tennessee Agricultural Experiment Station, and the University of Tennessee Department of Food Technology. Cooperation has also been provided by Crops Research Division, ARS, USDA; Agway, Inc.; the

Agricultural Engineering Departments of the University of Idaho and Texas A & M University, and others.

1. Insect Control Studies

Previous research at Lincoln, Nebraska, has shown that all developmental stages of all stored-grain insects studied can be killed by exposure for a few seconds to RF fields of sufficient intensity. Such treatment does not damage the wheat for germination or milling and baking purposes. This electrical treatment would be more expensive than using chemical insecticides for control purposes.

During the past year, a new pulse modulator for modulating a power RF oscillator was completed. This modulator provides pulses of RF energy as short as 50 microseconds to the experimental samples. By applying the RF energy in high-intensity pulses, higher intensity electric fields can be used, which may improve the efficiency of the method for insect control purposes. Even though pulse-modulated treatments were more successful in increasing the mortality of two species of stored-grain insects than unmodulated treatments at the same energy input, in most of the studies completed so far there was no advantage in pulse modulation. Evaluation of the pulse-modulation equipment is continuing, to provide more conclusive evidence regarding this method for use in stored-grain insect control.

The relative dielectric properties of grain and insects influence the amount of energy each absorbs from the RF electric field. Since the dielectric properties are frequency-dependent, knowledge of these properties over a wide frequency range would be helpful in determining optimum frequency ranges for insect control purposes. During the past year, methods were developed for determining these properties in the 200- to 20,000-Hz range and in the 50- to 250-MHz range. Data are being obtained by these methods and will be used to supplement data already obtained for insects and grain in the 1- to 50-MHz range.

2. Grain and Forage Crop Seed Studies

Previous experiments have shown that RF electrical treatments are effective in reducing the percentage of hard seed and correspondingly increasing normal germination in alfalfa, red clover, ladino clover, and, to a lesser degree, in sweetclover. Quality of RF-treated seed samples continued to hold up as well as untreated seed after 6 years in uncontrolled storage. Similarly, quality of RF-treated seed samples was retained, as well as untreated seed, after 6 years in a controlled storage atmosphere of 40° F. and 50 percent relative humidity. In studies with sweetclover seed, infrared and RF treatments were compared on three different lots of seed, two of which were conditioned to three moisture levels, and one lot to two moisture levels. Only RF treatments produced germination increases in two of the lots, while both infrared and RF treatments improved germination in the other lot. These increases were obtained only with seed dried to about 4 percent moisture and

raised the germination from near 50 percent to about 70 percent. One and two additional RF treatments of these samples produced small additional hard-seed reduction.

Germination and early growth of some varieties of seed corn were accelerated by RF treatments. Determinations of early growth were obtained by daily measurements of radicle and plumule growth. Faster early growth in some varieties could not be detected visually but was verified by statistical analysis. Further tests will be conducted to obtain more conclusive evidence of this acceleration for several seed corn varieties. In a very limited study, high-voltage d.c. and a.c. treatments of seed corn did not indicate any accelerated germination or early growth.

3. Vegetable and Ornamental Seed Studies

In work cooperative with CR, ARS personnel at Texas A & M University, germination of mesquite and huisache seed was improved by RF treatments, but these treatments failed to produce any germination in yaupon seed. In preliminary work, the germination of huisache seed was not improved. Further experiments will be conducted to continue the study of effectiveness of different combinations of variables in reducing hard-seed content and improving the germination of horticultural crop seed.

4. Cottonseed Studies

At Knoxville, Tennessee, in cooperation with CR, terminal investigations were conducted on 16-B-7 cottonseed. A supply of seed with a high percentage of impermeable seed was furnished by CR. These seeds were subjected to glow-discharge treatments and germinated in the laboratory. The untreated seed had 1 percent germination at 7 days as compared to 88 percent for the best glow-discharge treatment. The 16-B-7 cottonseed investigations are being transferred to North Carolina State University.

The investigations started in 1965 into the possibility of using the glow-discharge treatment to eliminate weak seeds was continued in 1966. Surviving plants were self-pollinated and the seed harvested. Seed from the 1966 self-pollinated plants were given heavy treatments and germinated. The best survival was among the seed which came from parent plants grown from seed which survived the heavy treatments in 1965. This work will be continued along lines suggested by CR personnel.

5. Soybeans

Field tests revealed no increase in yield or earlier germination of soybeans caused by glow-discharge treatments which had caused earlier germination in laboratory germinator tests. An experiment was designed to test the effect on soybeans of varying germinator temperatures, pressures, currents, and storage locations. The study is not complete, but preliminary indications are that a treatment which is superior to the others under one set of

conditions may be inferior to the other treatments under varying conditions. This study will be continued. Techniques have been developed to produce a satisfactory yield of oil and storage tests are to be made on untreated material and material given glow-discharge treatment. Both oil and whole beans will be used.

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AREA NO. 12: ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem. American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased an estimated 525 percent during the last 50 years. This increase is more than twice that for all livestock, 242 percent. Farm output per man-hour rose almost 8 percent from 1964 to 1965 to 153 percent of the 1957-59 average. The increase for crops as a whole was 2.7 times the gain for livestock. The amount of working time spent on livestock other than horses and mules (estimated to be 3,066 million man-hours per year in 1965) is 38.4 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market, but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year. Increased emphasis on automatic materials-handling equipment by livestock producers and equipment manufacturers has caused them to obtain advice and counsel of research workers. A continuing aggressive research program is essential to meet the developing needs of this segment of our National economy.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program with engineers working at Beltsville, and cooperatively with State experiment stations, USDA apiarists, and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development at the Washington and Illinois State Experiment Stations. Work on performance characteristics of upright silo unloaders and special duty motors is in cooperation with the Minnesota State Experiment Station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 4.1 scientific man-years; of this number 2.0 are devoted to bee equipment and 2.1 to equipment for livestock and poultry.

PROGRAM OF STATE EXPERIMENT STATIONS

The agricultural experiment stations of many of the States have research underway whose major objectives involve the obtaining of information on the uses to be made of electric energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm and in the home.

Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting, and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading and unloading devices, are a part of the overall program of investigations.

Much of the research is conducted cooperatively with the Department.

A total of 9.9 scientist man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Cattle Feeding Equipment

At Urbana, cooperative with the Illinois Agricultural Engineering and Dairy Science Departments, an automatic dairy cattle feeding system is being developed. This system will serve as a mechanization center for the study of the management and equipment interaction and for the development of an efficient overall system.

Work at the present time is concentrated on a materials handling system capable of full-automatic or manual operation. This system is made up of components developed in earlier research work on poultry, hog, and beef cattle feeding systems. The interdependence of controls and equipment was accentuated in this system. During the past 2 years, the major effort was to improve the reliability of the equipment. A metering device using a variable-speed DC motor controlled by a silicon controlled rectifier circuit proved a satisfactory means of metering concentrate on silage. A uniform discharge rate from an automatic silo unloader is required for a satisfactory feeding system. This has been difficult to achieve. However, a new system was developed that controls silage discharge rate to the acceptable accuracy of plus or minus 10 percent variation when used with a 2-motor top-unloading silo unloader. With a 1-motor silo unloader the variation in discharge rate is 15 to 20 percent.

A project was started to develop a pilotless and automated feed wagon capable of moving about over a programmed course and performing specified operations while following the course. The present means of guiding this vehicle is a

buried cable carrying a discrete alternating current. A detector on the vehicle locates the cable and keeps the vehicle centered over it. Initially, the vehicle was to be powered with electric motors. The energy requirement (100 kw.-hr.) was too great to be handled by present storage batteries; therefore, a gasoline engine with a hydrostatic transmission was used. The hydrostatic transmission permits smooth and continuously variable speed control of the vehicle. On-board equipment will be operated either by small electric or hydraulic motors. The vehicle will be subject to three modes of control: first, automatic programmed operation with instructions transmitted over the buried cable; second, manual control with an operator riding on-board the vehicle or walking to its side; and third, radio control which will be similar to manual control except that the operator can be far removed from the vehicle.

A pilotless vehicle will be especially useful on large feed lots where mechanization with augers and conveyors is not feasible. It will be useful for many other purposes on farms such as hauling material from field to storage, transporting workers in the field for harvesting purposes, or pulling or operating equipment over a prescribed path such as in a field or orchard where it could be used to spray trees.

During the past 3 years at St. Paul in cooperation with the University of Minnesota Agricultural Engineering Department, tests were made of the performance of electric motors currently being recommended for unloaders for vertical silos and for feed bunks. During this time six motor manufacturers submitted motors for testing. Five of them incorporated some of our results in designs for new motors. These tests were terminated during the past year. The performance requirements for the above motor applications have been fairly well established, and the dynamometer used for the tests had to be released for student class work.

At Pullman, in cooperation with the Agricultural Engineering and Animal Science Departments of Washington State University, work was renewed in February 1966 on an automatic horizontal or trench silo unloader. The automatic horizontal silo unloader previously developed was improved and a redesigned cutter unit was installed on the equipment. This new cutter is capable of faster removal of silage with less power than the original cutter and avoids some of the throw-down and scatter problems found with the old design. New controls for the system were incorporated which increase the unloader's ability to perform automatically and overcome the difficulty in controlling the lowering and advancing steps.

B. Apiary Equipment

At Madison, mechanical equipment for extracting honey and manipulating large two-queen hives suitable for use in Central States is being developed in cooperation with the Wisconsin Agricultural Engineering Department and the Apiculture Research Branch of ENT.

Field tests were completed which show that compressed air at 100 p.s.i. or more can be used with an inspirating nozzle to remove bees from honey-filled supers. The advantage of this device is its small weight and size which make it easy for the operator to handle. A high pressure air source is required which can usually be provided from portable equipment.

Flexible plastic comb sections were not accepted by bees either for brood rearing or honey storage. Firm plastics were acceptable. Insulated hive bodies, molded in one piece of extended polystyrene and coated with a high-density plastic, withstood handling very well. A small hive in an insulated plastic body is in good condition after a normal winter. The advantage of the hive body made of insulating material is that it will make it possible for the bees to be overwintered in the Northern States with fewer losses.

A vehicle is being developed for bee yard work. It is basically a 1/4-ton, four-wheel-drive truck equipped with a boom and on-board equipment such as an alternator and air compressor. This vehicle will enable the operator to inspect heavy two-queen hives during the production season and will provide the necessary energy sources for yard work away from conventional power sources.

At Tucson, the development of equipment suitable for apiary operations in the Southwest is being developed in cooperation with the University of Arizona Agricultural Engineering Department and the Apiculture Research Branch, ENT. While bees have accepted the hard or firm plastics, flexible plastics have not been acceptable to them. Investigation is continuing on flexible plastics. If a suitable plastic can be found, it will be possible to squeeze the honey from the combs rather than using radial or centrifugal extractors as is presently done. A new hive, designed and built in the shape of a cube, 18-7/8 inches on the side, was tested. It performed satisfactorily. This was the first attempt at changing the general hive dimensions to ones more suitable for mechanical handling than those presently used.

The air flow within the hive has been thought to be influenced by bees fanning the air to cool the hive in hot weather. Measurements made thus far show only air movement which can be explained by natural convection. Additional tests with other instrumentation will be made to determine if this finding is correct.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Cattle Feeding Equipment

Daum, D. R. and Puckett, H. B. 1966. An electronic continuous-flow silage meter. *Agricultural Engineering Journal*. 47(6):332-334. June.

Olver, E. F., Harshbarger, K. E., and Puckett, H. B. 1966. Automated feed system. *Agricultural Engineering Journal*. 47(12):660. December.

Puckett, H. B. and Klueter, H. H. 1966. Auger-feed injector for pneumatic conveyor. Transactions of ASAE. 9(3):407-408.

Puckett, H. B. and Klueter, H. H. 1966. Pneumatic conveyor for distributing farm feed. USDA, ARS, Production Research Report No. 92. August.

Apiary Equipment

Detroy, B. F. 1967. Valve for filling honey cans. USDA, ARS 42-130. January.

AREA NO. 13: ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem. Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain, and peanuts, and are extremely effective in maintaining the quality of stored fruits and vegetables, and in cooling milk. Current scientific and economic developments indicate that production of vegetables and flowers in the future may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. The lack of available electric energy in remote areas of a farm has limited the use of electric devices. Conversion of solar to electric energy at the site may eventually eliminate this energy shortage.

USDA AND COOPERATIVE PROGRAM

A program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with Crops Division scientists on basic studies of light and thermal environment and their relation to plants in growth chambers. Equipment for the application of carbon dioxide to plants is under development at Beltsville and at Kansas State University in cooperation with the Departments of Agricultural Engineering, Horticulture and Physics. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division.

The influence of electric equipment and environment on health and disease is being studied in USDA laboratories at Athens, Georgia, and State College, Mississippi. Studies on the performance of milk handling equipment are underway at Beltsville in cooperation with the Animal Husbandry Research Division and the Eastern Utilization Laboratory. Performance characteristics are being determined for turf soil heating with electric cable at Purdue University in cooperation with the Departments of Agricultural Engineering and Agronomy of the Purdue Station; also at Beltsville in cooperation with the Crops Research Division; and at St. Paul, Minnesota, in cooperation with the Departments of Horticulture and Agricultural Engineering. Performance characteristics of equipment are being studied for maintaining environment for conditioning potatoes for processing. This work is in cooperation with the Departments of Agricultural and Chemical Engineering, Horticulture and Plant Pathology of the University of Minnesota and the Market Quality Research Division and the Transportation and Facilities Research Division, ARS, East Grand Forks.

The Federal scientific effort devoted to research in this area totals 5.6 scientific man-years; of this number 2.6 are devoted to plant environment equipment; and 3.0 to poultry environment equipment.

PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation, and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that heat, light, space, and other factors have on farm animals; soil, light, and atmospheric conditions on plants; and temperature, humidity, and gases on stored products. Special attention is being given to development of means for collection, storage, and use of solar energy for structural heating and crop conditioning.

A great portion of this research is cooperative with the Department.

A total of 4.9 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Equipment for Poultry Environmental Studies

In cooperation with the Poultry Research Branch at Beltsville, Maryland, the fifth year of a 5-year genetic selection of laying stock responsive to less than a 24-hour-day cycle was completed. Five years' summary shows the following results: (1) 18- and 24-hour selected populations showed advantages in egg production over the controls of 8.1 and 6.2 percent, respectively, in the four generations; (2) realized genetic progress obtained by a system of hen family and individual selection was greater than anticipated under both environments; and (3) birds matured earlier with a constant 6-hour photo-period than with a step-down program under an 18-hour environment. The egg production curve of 18-hour population shows that these birds did not come into production as soon as those in the 24-hour population and suggests that in future "short day" studies their age at sexual maturity should be decreased by giving them additional exposure to light.

The electronic data-recording system used in the above study showed an overall 5-percent error in recording time of lay for 95,932 eggs from both houses (18- and 24-hour). This involved 785 hens for six 30-day laying periods. Four major sources of error were (1) eggs not rolling down cage floor to activate egg sensor, (2) eggs rolling under or over sensor arm, (3) sensor not resetting properly, and (4) error, but no visible cause noted at egg collection.

At the Southeast Poultry Research Laboratory, Athens, Georgia, four air velocity/heat tolerance tests were conducted as a followup to last year's studies. Three tests were at air temperatures less than 100° F. and one greater than 100° F. In each of the tests, six birds were placed in an air stream with a velocity of approximately 20 f.p.m. and six at approximately 500 f.p.m. velocity. At air temperatures less than 100° F., heat stress was alleviated by the higher air velocities, as indicated by lower body temperatures, heart rates, and respiratory rates. The opposite occurred at air temperatures greater than 100° F., as the respiratory rates and body temperatures increased more at the high air velocity than at the low. Heart rates were only slightly affected by air velocity.

Considerable engineering effort went into the design of research equipment and facilities for the Southeast Poultry Research Laboratory. Model III isolation cabinets were designed and 72 were purchased. Accessories for 36 of these cabinets were designed and installed. Equipment was designed and installed to provide filtered positive-pressure ventilation in two additional poultry houses. Five old isolation cabinets were converted to positive pressure for producing disease-free chicks. Five long-life, dust-tight psychrometers were designed and built. A precision air flow calibrating system was designed and built. Implantable radio telemetry equipment was built and tested.

At the South Central Poultry Research Laboratory, State College, Mississippi, one of the existing poultry houses was converted into a windowless unit with controlled temperature, humidity, light, and ventilation. Operation of this facility indicates that close control of humidity and ventilating rate is necessary to control dust and ammonia, and that these requirements are drastically affected by bird density. Direct control of the ventilating rate by exhaust dew-point temperature appears to offer advantages over control by relative humidity-temperature systems. Environmentally controlled chambers have been designed and procured which should reduce problems inherent in recirculation-type chambers.

In the studies to determine the effects of exposure of broilers to temperature extremes, results show that broilers relatively disease-free or infected only with Mycoplasma gallisepticum can withstand severe temperature extremes if the duration is short. Such exposures do not significantly affect mortality, condemnation, or 8-week body weights. The conclusion drawn from this work is that temperature alone is not the stress factor which it is generally thought to be. This should open the way for studies to determine what other factors are important stresses, and how these factors might be affected indirectly by temperature.

B. Plant and Product Environmental Equipment

1. Carbon Dioxide Fertilization

At Manhattan, Kansas, chrysanthemums were misted with tap or carbonated water or supplied additional CO₂ from a gas burner in continuing tests in

commercial-type 20' x 40' glass greenhouses. During the winter and early spring the house with the natural gas burner produced the best plants. In the late spring, the plants misted with carbonated water had the best growth. During the summer and fall seasons the plants misted with carbonated water showed improved growth over those misted with tap water. The natural gas burner may not be used during the summer and fall seasons due to increased ventilation requirements.

The traveling nozzle produced a more uniform dispersion of the mist over the entire bench width and proved superior to a plastic hose with nozzles spaced at about 2-foot intervals down the center of the bench.

Leaf lettuce plants were studied in plant growth chambers. In one chamber the plants were misted with carbonated water while in a check chamber they received no mist. Room air was circulated through both chambers and then exhausted to the atmosphere. Four temperatures were studied in this first series of tests, from 10° C. to 33° C. in steps of about 7.5° C. Results have not yet been analyzed.

Carbon dioxide concentration was monitored in both the greenhouses and the plant growth chambers. Leaf temperatures and light intensity were periodically measured to assure approximately equal radiation on the plants in both chambers.

At Beltsville, Maryland, tests on the use of carbonated water to furnish additional CO₂ to plants were discontinued as consistently negative results were obtained instead of earlier flowering and accelerated growth as reported from Kansas. The difference may be due to soil types, water hardness, solar radiation, temperature, management, or a combination of these factors. The addition of CO₂ gas in the plexiglass test chambers has given additional growth and earlier flowering in nearly every type of plant.

2. Plant Growth Lighting, Radiation, and Instrumentation

At Beltsville the Phyto-Engineering Laboratory was completed and occupied although all of the auxiliary services were not installed. The construction, moving, and setting up of equipment required a large percent of the staff effort. The first planned controlled-environment experiment was started during March 1967.

The motion meter was used by the Plant Physiology Pioneering Laboratory to measure cyclic movements of mimosa, a light-sensitive plant. It was also used by them to study geotropism. A working model instrument was developed from the motion meter to measure leaf thickness to be used in CR hay breeding investigations.

3. Electric Equipment for Soil Warming for Plant Growth

Investigations concerning evaluations of electric soil heating cable systems were continued in Indiana, Minnesota, Maryland, and Missouri. Objectives of the research were to evaluate performance of systems, to develop a method for estimating the energy needed to operate these systems, and to determine the heat transfer characteristics of turf.

Study of installation and operation of commercial units is one of the objectives of this program. Two large stadium fields were equipped with heating cables during 1966. Instrumentation was installed in the fall in Civic Center Busch Memorial Stadium, St. Louis, to collect temperature and energy consumption data that can be correlated with weather conditions and grass response. Cooperating in the evaluation of the performance are Link's Nursery and the Civic Center Redevelopment Corporation. The sod placed on this field in early spring was physically killed during the fall. Resodding will take place in mid-winter. Without soil warming, this would be impossible. The other commercial installation was in the Air Force Academy's Falcon Stadium. The performance of these two systems, and others as they are placed in operation, will be evaluated.

Investigations were continued at Lafayette, Indiana, in cooperation with the Departments of Agronomy and Agricultural Engineering of the Purdue Agricultural Experiment Station, to check systems of controls for electric soil warming installations and to develop a method to estimate energy use. Installation of five 10' x 30' plots was not completed until mid-January. As a result, the heat loss was not buffered during the fall and the soil in the plots was frozen when heating began. Bluegrass, primarily Merion, came out of dormancy and grew during the remainder of the winter. Blades greened up about 6 weeks earlier than the unheated areas. As before, seedheads also formed about 6 weeks before normal. Zoysia did not begin greening up until March 23 on the heated plots and April 25 on unheated areas.

Experimentation to study the potential use of electric heating cables under ornamental shrubs was continued cooperatively with the Purdue Department of Horticulture. The objective is to eliminate winterkill due to desiccation and thereby extend the growing period for certain temperature-critical evergreens. Although the rootzone of the plants were kept thawed and winterkill was reduced, desiccation still occurred.

An operating system in a 300-sq.-ft. experimental putting green showed that heat loss from a tight, close-cut bentgrass surface is similar to bare ground, rather than normal lawn turf. The heated turf did not green up much earlier than the unheated turf although soil temperatures were maintained above 30° F. as compared with 20° F. in the unheated turf. Little advantage was observed from heating under these conditions.

Part of this research program is carried out at Beltsville, Maryland, in cooperation with the Forage and Range Crops Research Branch, to study the

effectiveness of soil heating in a location with a milder climate than central Indiana. For the second consecutive winter, temperatures correlated with visual observations indicated that the need for supplemental heat for blue-grass turf is marginal for climates similar to the Beltsville area.

Heated turf plots were operated at St. Paul, Minnesota, in cooperation with the Departments of Soil Science, Horticulture, and Agricultural Engineering. During the winter of 1966-67 the plots were snow covered all winter. With very little frost in the ground before the snow cover came, even the unheated plots had sufficient growth during the winter to knit the sod to the subsoil. If the fine points of performance of heated turf for the northern climates are to be determined, it will be necessary to control the climate and snow cover above the plots.

4. Environmental Equipment for Conditioning Potatoes for Processing

In Minnesota, cooperative work is underway to evaluate the effects of different storage temperatures on tubers used for processed flakes and to develop a frost-free refrigeration system for maintaining low storage temperatures during an approximately 9-month storage period. The same experiments were repeated for several years to minimize differences due to varying environmental conditions from one growing season to another. Variety differences in reaction to storage temperatures show up. Some varieties have a short dormancy period and start sprouting if held at 50° F. Observations indicate pressure bruising problems when the temperature in bins of high depth is elevated to 65° F. for conditioning.

C. Solar Equipment

A project is underway at the Atomic Energy Center, Lahore, West Pakistan, using PL 480 funds for the development of solar powered equipment for operating a small irrigation pump. A 258-sq.-ft. reflecting surface was built from 380 flat mirrors. The solar energy falling on the mirrors is concentrated on a boiler. Temperatures of 400° C. on the face of the boiler and steam at 25 p.s.i. pressure have been produced. Steam from the boiler has been used in an engine to produce 2 horsepower. The overall maximum efficiency for the entire system is 7.7 percent. A piston-type water pump coupled to the engine pumps 500 gallons of water per hour from a water table 22 ft. below the check valve and against a total head of 28 ft. Plans call for the replacement of the presently used back-coated silvered mirrors with aluminum mirrors and the use of a heliostat to direct the solar energy continuously on the boiler.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Equipment for Poultry Environmental Studies

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Plant and Product Environmental Equipment

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- Mowry, G. R. and Lipper, R. I. 1966. Supplementary carbon dioxide for plant growth by carbonated water misting. Kansas Committee on Relation of Electricity to Agriculture. Forty-first Annual Report.

AREA NO. 14: FARM ELECTRIC SERVICE AND INSTRUMENTATION

Problem. Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard. More economical means of providing adequate wiring are needed.

The rapidly increasing demand of Midwestern farmers for large motors is becoming of concern to farm power suppliers. This increase in demand is attributable to the shift from ear corn to shelled corn harvest. Shelled corn is often harvested at high moisture contents and should be dried about as fast as it is harvested. Manufacturers are offering for sale new types of large single-phase motors and several types of phase converters to permit three-phase motors to operate on single-phase lines. The operating characteristics and selection criteria for this new equipment have not been fully established.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

USDA AND COOPERATIVE PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises, and weather require that studies also be made in other areas. Data obtained in cooperation with members of the Farm Wiring Committee of the American Society of Agricultural Engineers are analyzed in demand studies and in developing and substantiating changes to the National Electrical Code.

At Beltsville, a program is underway to develop and provide accurate, practical, and sometimes complex instrumentation for specific program needs.

Federal scientific effort devoted to research in this area totals 2.0 scientific man-years. Of this number 1.0 is devoted to energy distribution and farm electric demand and 1.0 to instrumentation.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The agricultural experiment stations of a few of the States have research investigations in progress studying the electric demands of farms and the major appliances used on farms in order to evaluate the effects of these demands on farmstead distribution systems. Exploration is also underway on the possibility of developing a safe distribution system for the farmstead using voltages which are higher than those currently allowed under the National Electrical Code.

Many of the studies are cooperative with the Department.

A total of 2.1 scientific man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Energy Distribution and Demand

At Ames in cooperation with the Iowa Agricultural Experiment Station, studies of the demands of farmstead loads were made to increase the effectiveness and reduce the cost of electric service. Demands for both 1.875-minute and 15-minute intervals were measured for farmstead and electric house-heating loads. These data provide an estimate of maximum energy use which is necessary for the proper sizing of distribution transformers and farmstead wiring. The 1.875-minute demands usually exceeded the conventional 15-minute demands for the same loads by large margins. The maximum 1.875-minute demand for one electric house-heating load was more than double the maximum 15-minute demand. Farmstead loads also had higher 1.875-minute demands with values ranging as high as 73 percent greater than the 15-minute demands for the same loads. Power suppliers have indicated interest in this information for the proper sizing of farm services.

Phase converters to operate large three-phase motors from single-phase lines have continued to draw attention from both rural users and power suppliers. As farm operations have changed, requirements for large motors have increased. Phase converters to operate three-phase motors offer one approach to the procurement and operation of larger motors, but more information is needed for their proper application. Studies of one of the newer types, the rotary phase converter, have been carried on at Iowa State University to obtain information needed for their use. Emphasis has been primarily on the temperature rises encountered in the motors under various conditions of loading and operation with rotary phase converters. These data showed that excellent operation can be obtained if the characteristics and limitations are understood. Additional study should contribute to a better understanding and utilization of phase converters for the operation of integral horsepower motors.

An exploratory study was made to determine the direction research might take in reducing the cost of farm wiring. Data on costs of material and labor for wiring and on the installed cost of meter loops of various designs were assembled from power suppliers and farmsites. An analysis of these costs indicated that research directed toward the problem areas in service entrances and farm wiring could contribute to the reduction of wiring cost and provide better farmstead service.

B. Research Instrumentation

At Beltsville, Maryland, a spectroradiometer was used to investigate the spectral irradiance of light sources and the spectral transmittance characteristics of various materials. Light source and material measurements were in support of insect light-trap and plant-growth projects. An analytical method based on statistical techniques was developed to determine the effects of aging on the spectral output of blacklight lamps used in insect traps. A comparison curve was calculated from measurements on new (pre-aged) lamps and on lamps used one, two, and three seasons. There was no significant spectral shift with lamp age. The analytical method was revised and extended to develop a comparison curve for lamps used in plant growth chambers.

Field use of meters previously constructed for measurement of the ultraviolet irradiance of lamps in insect traps has shown them to be satisfactory. There is need for a recording version of the meter. Development of such a device was initiated.

Spectral measurements of a plant-growth-chamber fluorescent lamp, powered by a commercially made continuously variable d.c. supply, showed no spectral shift throughout the voltage control range.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Energy Distribution and Demand

Altman, Landy B., and Pringle, H. S. 1966. Farm wiring in the new NEC code. Agricultural Engineering Journal. 47(9):478-480. September.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Area & Sub-heading
AE al	Weed, insect pest, & plant disease control machinery Program leadership	Beltsville, Md.		
AE al-1 (Rev.#2)	Equipment for application of pesticides, defoliant, fertilizers and seeds from agricultural aircraft.	Wooster, Ohio & Forest Grove, Ore.	Yes	3-H-1
AE al-4	Develop equipment & techniques for application of insecticides & fungicides to crops by ground machines.	Wooster, Ohio & Forest Grove, Ore.	Yes	3-F-1
AE al-6 (Rev.#2)	Aerial spray equipment for forest insect control.	Beltsville, Md.	Yes	3-I-1
AE al-11 (Rev.)	Equipment for the application of chemicals to the soil for control of soil pests.	Wooster, Ohio	Yes	3-B-1
AE al-12 (Rev.)	Investigations of equipment & techniques for mechanical & chemical control of weeds in crops.	Columbia, Mo. Ames, Iowa Stoneville, Miss.	Yes	3-D-1
AE al-15 (sup. part AEc5-2)	Equipment for the above-ground application of agricultural chemicals in cotton.	Auburn, Ala. Shafter, Calif. Lubbock, Tex. Stoneville, Miss.	Yes	3-E-2
AE al-16 (sup. part AE c5-2)	Equipment for soil incorporation of chemicals for cotton pest control.	Stoneville, Miss. Shafter, Calif.	Yes	3-E-1
AE al-17	New mechanical and/or physical methods for insect control on grain crops.	Tifton, Ga.	Yes	3-C-2
AE al-18	Developing equipment for practical control of insects on grain crops grown in the Southeast.	Tifton, Ga.	Yes	3-C-2
AE al-19	Detecting and measuring spray deposits on corn ears and silks.	Tifton, Ga.	No	
AE al-20	Mechanical methods of destroying fallen cotton squares.	State College, Miss.	Yes	3-E-3
AE al-21	The development and evaluation of equipment and techniques for broadcast applications of granular pesticides with air blast machines.	Wooster, Ohio	No	
AE al-22	Evaluation of devices for distribution and metering of pre-emergence herbicides on the soil and mixed with the soil in the surface layer.	Ames, Iowa and Columbia, Mo.	Yes	3-D-2
AE al-23 (sup. AE al-3)	The development and evaluation of equipment for control of corn insects in the Midwest.	Wooster, Ohio, and Ames, Iowa	Yes	3-C-1
AEal-24(C)	Equipment for application of agricultural materials from fixed-wing aircraft.	State College, Miss.	Yes	3-H-2
AE al-25	Pesticide equipment and techniques for control of fruit, vegetable, and field crop insects and diseases.	Yakima, Wash.	Yes	3-G-1
AE-0-0-2 (DOD)	Equipment and techniques for applying herbicides to vegetation in Puerto Rico and Texas.***	Mayaguez, P.R. College Sta., Tex.	Yes	3-J-1
A10-AE-5 (PL-480)	Application of air jets with a vortex to improve penetration of air-borne insecticide sprays into dense foliage of citrus trees.	Rehovot, Israel	Yes	3-K-1
Charter	Physics of Fine Particles, Pioneering Research Laboratory.	Wooster, Ohio	Yes	3-A-1
AE a2	Planting & fertilizing equipment and practices Program leadership	Beltsville, Md.		
AE a2-8 (sup. AEa2- 1 rev.)	Equipment and practices for pasture and hay land establishment and maintenance.	Beltsville, Md. Bushland, Tex. Athens, Ga.	Yes	2-B-1

* Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967.

*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub- heading
AE a2-9	Development of equipment and techniques for cotton planting.	St. College & Stoneville, Miss. Shafter, Calif. Auburn, Ala. Lubbock, Tex.	Yes	2-C-1
AEa2-10(C)	Design and development of range seeding equipment for use with brush eradication equipment in the arid Southwest.	Las Cruces, New Mexico	Yes	2-B-2
AE a2-11 (sup. AEa2- 2 rev.)	Planting and fertilizing placement machinery for cultivated field crops & vegetable crops.	Ariz., Fla., Ga., Md., Mich., Nev., Tex., Va., Wash.	Yes	2-A-1 2-D-1
AEa2-12(G)	Modification and control of pertinent properties of tobacco during production and curing as related to health factors. **	Raleigh, No. Car.	Yes	2-A-2
AE-00-1	Equipment and methods for decontamination of agricultural lands affected by radioactive fallout.	Beltsville, Md.	Yes	2-E-1
AE a3	Tillage machinery investigations Program leadership	Beltsville, Md.		
AE a3-6 (Rev. #1)	Development of tillage machinery that will reduce soil erosion and runoff.)	Ames, Iowa	Yes	1-E-1
AE a3-11	Equipment for transferring soil layers and improving surface soil characteristics.	Stoneville, Miss.	Yes	1-B-2
AE a3-12 (sup. AEa3- 1, -2, & -4)	Basic studies of soil-working tools.	Auburn, Ala.	Yes	1-B-4 1-D-1
AE a3-13 (sup. AEa3- 3 & 5)	Basic studies of traction and transport devices.	Auburn, Ala.	Yes	1-A-1 1-B-1
AE a3-14 (sup. AEa3- 7 & 8)	Characterization of dynamic properties and physical conditions of soil in relation to tillage and traction.	Auburn, Ala.	Yes	1-B-5 1-C-1
AE a3-15 (sup. AEa3- 6 Rev.)	Development of criteria for tillage machinery that will reduce soil erosion and runoff.	Ames, Iowa	Yes	1-E-1
E15-AE-1 (PL-480)	Development of methods and equipment for breaking up cohesive clay soils into small clod sizes up to a deep depth.	Bologna, Italy	Yes	1-F-1
E21-AE-4 (PL-480)	Investigation of energy requirements for tillage by combining active and passive tillage machines. **	Warsaw, Poland	Yes	1-F-4
A10-AE-3 (PL-480)	Soil structure - tillage interactions.	Rehovot, Israel	Yes	1-F-2
A10-AE-4 (PL-480)	Effect of knife angle and velocity on cutting of roots and rhizomes in the soil.	Beit Dagan, Israel	Yes	1-F-3
AE b1	Farm housing Program leadership	Beltsville, Md.		
AE b1-2 (Rev. #2)	Experimental farmhouses ***	Beltsville, Md.	No	
AE b1-5	Optimum attic fan arrangements for modern rural dwellings.	Athens, Ga.	Yes	8-C-1
AE b1-6	Effect of window and floor coverings on thermal environment in modern rural dwellings.	Athens, Ga.	Yes	8-A-1
AE b1-7	Effect of window and floor coverings on noise environment in modern rural dwellings	Athens, Ga.	Yes	8-A-2

*Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967.

** Initiated during reporting year.

*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary of Progress	Area & Sub-heading
AE b1-8	Rural dwelling plan development.	Beltsville, Md.	Yes	8-A-3, 8-D-1
AE b1-9	Planning guides for housing units for senior citizens.	Beltsville, Md.	No	
AE b1-10	Planning guides for housing units for migratory and seasonal farm workers.	Beltsville, Md.	Yes	8-D-2
AE b2	Livestock shelters			
	Program leadership	Beltsville, Md.		
AE b2-1 (Rev.#2)	Determination of environmental design criteria for poultry house design.	Beltsville, Md.	Yes	9-D-1
AE b2-7 (Rev.)	Livestock shelters for southeast.	Tifton, Ga.	No	
AE b2-8	Evaluation and development of equipment and procedures for reducing chemical hazards associated with the control of livestock insects.	Kerrville, Tex.	Yes	9-G-1,2,3
AE b2-9	Evaluation of radiant fluxes from the sky, ground and surroundings and their influence on the radiant environment of livestock.	Davis, Calif.		
		Columbia, Mo.	Yes	9-F-1
AE b2-10	Use of models for analyzing farmstead layouts***	St. Paul, Minn.	Yes	10-E-1
AE b2-11	Time standards for farmstead work elements.	St. Paul, Minn.	Yes	10-E-2
AE b2-12	Principles of planning farmstead layouts to reduce labor required in production of livestock and poultry.	Davis, Calif.	Yes	9-A-1
AE b2-13	Development of prototype environmental cabinet for poultry disease research.	Athens, Ga.	Yes	9-D-2
AE b2-14	Design and layout criteria for labor-saving structures and related equipment for feeding cattle.	Davis, Calif.	No	
AE b2-15	Environmental stress zones as criteria for design of heating, ventilating and air-conditioning equipment for turkey production.	St. Paul, Minn.	Yes	9-D-4
AE b2-16	Bioengineering studies relating to environmental factors and physiological responses of swine with emphasis on humidity and high temperatures.	Davis, Calif.	Yes	9-C-1,2,4
AE b2-17	Bioengineering studies of factors affecting the relationship of environment and growth and feed utilization of beef cattle.	Davis and El Centro, Calif.	Yes	9-B-1
AE b2-18	Development and test of shelters and related equipment for protecting farm animals from hot, dry climates.	Davis and El Centro, Calif.	Yes	9-B-1, C-3,5
AE b2-19	Measurement of eggshell thickness with radioactive isotopes.	Beltsville, Md.	Yes	9-D-5
AE b2-20	Bioengineering studies relating climatic factors and physiological responses of dairy cattle**	Columbia, Mo.	Yes	9-A-2
AE b2-21	Buildings and related equipment for sheltering farm animals, principally dairy cattle in the Midwest.	Columbia, Mo.	Yes	9-A-2
AE b2-22	Experimental procedures and facilities for engineering aspects of toxicology and livestock insect research**	College Sta., Tex.	Yes	9-G-4
AE b3	Storages and related equipment for farm products			
	Program leadership	Beltsville, Md.		
AE b3-12	Farm storage of high moisture grain.	Ames, Iowa	No	
AE b3-13	Silage and other forage density measurement with radioactive isotopes.	Beltsville, Md.	Yes	7-A-1

*Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967.

**Initiated during reporting year.

***Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Incl. in Summary Area & of Sub- Progress heading
AE b3-14 (Rev.)	Pressures of wheat and soybeans on bin walls, floors and structural members.	Ames, Iowa	No
AE b3-15	Structures and related equipment for control of plant environment.	Beltsville, Md.	Yes 7-B-1,2, 3,4
AE b3-17	Structural design criteria for large tower silos.	Beltsville, Md.	No
AE b4	Farm building plan exchange and information Program leadership	Beltsville, Md.	
AE b5	Materials and construction methods for farm buildings Program leadership	Beltsville, Md.	
AE b5-6	Incorporation and application of hyperbolic paraboloid (HP) theory to the structural use of sheet materials in farm structure roof design.	Beltsville, Md.	Yes 10-C-1
AE b5-8	Floor deck and slab studies (primarily for rural dwellings)	Beltsville, Md.	Yes 8-B-1
AE b5-10	Investigations of the nature and magnitude of wind forces on farm structures.	Blacksburg, Va.	Yes 10-A-1
AE b5-11	Building foundations in expansive clay soils.	Starkville, Miss.	No
AE b5-12	Farm service building plan development.	Beltsville, Md.	Yes 7-C;9-A-3, B-3,C-6, D-6;10-C-2
AE b5-13	Prototype low-cost house construction.	Charlestown,W.Va.	
AE b5-14	Safety features for rural structures.	Oakland, Md.	Yes 8-B-2,C-2
AE b5-15	Influence of construction, equipment, and management of broiler houses on airsacculitis and condemnations.	Beltsville, Md.	Yes 10-B
AE b6	Farmstead water supply and wastes disposal Program leadership	State College, Miss.	Yes 9-D-3
AE b6-2 (Rev.)	Design criteria for livestock farmstead water systems.	Beltsville, Md.	
AE b6-3	Characteristics of farm animal manures affecting design of disposal facilities.	College Park,Md.	Yes 10-D-1
AE b6-4	Farm animal manure disposal lagoons.	College Park,Md.	Yes 10-D-3
AE b6-5	Pesticide pollution of farmstead water supplies.	College Park,Md.	Yes 10-D-3
A7-AE-3 (PL 480)	Studies on use of pure strains of algae and mixed algae-protozoa and algae-bacteria cultures in sewage treatment.	Beltsville, Md.	Yes 10-D-2
AEcl	Cotton ginning investigations Program leadership	Baroda, India	Yes 10-D-4
AEcl-24 (Rev)	Fundamental mechanisms of nep formation in cotton	Beltsville, Md.	
AEcl-28 (Rev)	Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed***	Mesilla Park, N.M.	Yes 6-E-3
AEcl-34	Improving cotton ginning performance through cotton quality evaluations & their relationships to ginning and associated operations	Clemson, S. C.	Yes 6-C-1
AEcl-35	Improving extra long staple cotton ginning means & methods		6-E-1 6-F-1
AEcl-36	Roller gin adjustment for optimum performance	Mesilla Park, N.M.	Yes 6-B-2 6-E-4
AEcl-37	Measurement of raw cotton length for cotton ginning evaluation	Mesilla Park, N.M.	No 6-F-2
AEcl-38	Gin stand research and development	Stoneville, Miss.	Yes 6-E-2
		Clemson, S. C.	

* Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967.

** Initiated during reporting year.

*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Areas & Sub-heading
AEc1-39	Materials handling & collection at cotton gins	Stoneville, Miss. Mesilla Park, N.M. Clemson, S. C.	Yes	6-A-1 6-D-1 6-I-1
AEc1-40	Effects of production & harvesting methods & practices on cotton ginning & fiber quality	Stoneville, Miss. Clemson, S. C. Mesilla Park, N.M.	Yes	6-F-3 6-F-8
AEc1-41	Cotton bale packaging improvement	Stoneville, Miss.	Yes	6-H-1
AEc1-42	Relationship of temperature, moisture, impact, & tensile stresses during ginning to fiber strength, length distribution, & yarn quality	Stoneville, Miss.	Yes	6-F-5
AEc1-43	Determinations of electrostatic properties of cotton	Mesilla Park, N.M. Clemson, S. C.	Yes	6-F-4
AEc1-44	Cotton quality measurements for evaluating the effects of ginning**	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-F-6 6-F-7
AEc1-45	Analysis and Improvement of Equipment for removing foreign matter from lint cotton at the gin**	Stoneville, Miss.	Yes	6-G-1
AEc1-46	A Study of Seed Cotton cleaning principles aimed at improvements and new applications**	Stoneville, Miss.	Yes	6-C-2
AEc1-47	Development and Evaluation of an integrated automatic moisture control system for cotton ginneries**	Stoneville, Miss.	Yes	6-B-1
AEc3	Equipment for harvesting & farm handling of fruits & vegetables Program leadership	Beltsville, Md.		
AEc3-21	Mechanical injury of potatoes-evaluation, causes & prevention***	E. Grand Forks, Minn.	No	
AEc3-25	Equip. & methods for harvesting & field handling citrus fruit***	Lake Alfred, Fla. Davis, Calif.	No	
AEc3-26	Mechanical aids and harvesting equip. & methods for picking apples for the fresh market	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-1 4-C-2
AEc3-27	Mechanized picking of apples & pears for processing outlets.	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-3
AEc3-28	Development of equip. & methods for harvesting of apples & pears from trees of different sizes, shapes & planting distances.	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-2
AEc3-29	Development of continuous-type self-propelled machine for harvesting cultivated blueberries***	E. Lansing, Mich.	Yes	4-C-4
AEc3-30	Equip. & methods for maintaining quality of cherries during mechanical harvesting & handling	E. Lansing, Mich.	Yes	4-C-5
AEc3-31	Methods & equip. for harvesting prunes grown in the Coastal Region of Calif.	Davis, Calif.	No	
AEc3-32	Bark damage to fruit trees resulting from mechanical shakers***	Davis, Calif. Lake Alfred, Fla. E. Lansing, Mich.	No	
AEc3-33	Development of methods & equip. for multirow harvest of potatoes	E.G. Forks, Minn.	Yes	4-F-1
AEc3-34	The development of equip. for application of dust to seed potatoes***	E.G. Forks, Minn.	Yes	4-F-3
AEc3-35	The development of equip. & methods for harvesting coffee	Honolulu, Hawaii & Kona, Hawaii	Yes	4-A-6
AEc3-36	Equip. & methods for pollination of dates	Riverside, Calif.	Yes	4-A-7
AEc3-37	Development of improved harvesting procedures & equip. for clingstone peaches	Davis, Calif.	Yes	4-C-6
AEc3-38	Equipment and methods for harvesting pears**	Davis, Calif.	Yes	4-C-7
AEc3-39	Equipment & methods for harvesting sweet cherries**	Davis, Calif.	Yes	4-C-8
AEc3-40	Physical & rheological properties of bark & wood of fruit trees**	E. Lansing, Mich.	Yes	4-C-9

* Reporting year for all projects concerned with cotton---July 1, 1966 to June 30, 1967.

** Initiated during reporting year.

*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Areas & Sub- heading
AEc3-41	Modifying trees to facilitate citrus harvesting**	Lake Alfred, Fla. Riverside, Calif.	Yes	4-A-1
AEc3-42	Chemical, electrical and physical means of loosening fruit attachments and causing abscission of citrus fruit on trees**	Lake, Alfred, Fla. Riverside, Calif.	Yes	4-A-2
AEc3-43	Development of methods and equipment for harvesting citrus using detachment devices which do not make contact with the fruit**	Riverside, Calif. Lake Alfred, Fla.	Yes	4-A-3
AEc3-44	Development of equipment & methods for harvesting citrus using detachment devices which make contact with the fruit**	Lake Alfred, Fla. Riverside, Calif.	Yes	4-A-4
AEc3-45	Development of aids for increasing the efficiency of workers who harvest citrus**	Lake Alfred, Fla. Riverside, Calif.	Yes	4-A-5
AEc3-46	Development of equipment and methods for dethorning pruning, tying, and bagging in the production of dates**	Riverside, Calif.	Yes	4-A-8
AEc3-47	Instrument for measuring susceptibility to bruising of potatoes during harvesting**	E. Grand Forks, Minn.	Yes	4-F-2
AEc4	Farm seed cleaning & handling Program leadership	Beltsville, Md.		
AEc4-4 (Rev)	Seed cleaning research applied to specific problem mixtures***	Corvallis, Ore.	Yes	5-A-1
AEc4-8 (Rev)	Development of a centrifugal-pneumatic seed separator	Corvallis, Ore.	No	
AEc4-13	Development of a high-speed scalper for seed crops***	Corvallis, Ore.	No	
AEc4-14	Development of components for cutting, picking up, threshing, & cleaning field seed crops	Corvallis, Ore.	Yes	4-D-1
AEc4-15	Uniform flow-seed feeder**	Corvallis, Ore.	Yes	5-A-2
AEc5	Equipment for mechanical cotton production Program leadership	Beltsville, Md.		
AEc5-4	Equipment & techniques for crop residue disposal in crop production	Stoneville, Miss.	Yes	1-B-1
AEc5-5	Equipment & methods for optimum seedbed preparation for cotton	Lubbock, Texas Shafter, Calif.	Yes	1-B-3
AEc5-6	Power requirements of cotton production implements	Shafter, Calif.	No	
AEc5-7	Synthetic mulches for improving cotton stands	Stoneville, Miss. Lubbock, Texas	No	
AEc5-8	Cooperative studies on the effects of production practices on the end use quality of cotton & cottonseed	Stoneville, Miss. Auburn, Ala. Lubbock, Texas	Yes	4-B-1 4-B-5
AEc5-9 (Rev)	Evaluation & development of cotton harvesting machines	Stoneville, Miss. Lubbock, Texas Auburn, Ala.	Yes	4-B-3
AEc5-10	Reduction of moisture added to seed cotton by spindle-type harvesters	Stoneville, Miss. Shafter, Calif.	No	
AEc5-11	Sources of trash in cotton harvesting	Shafter, Calif. Stoneville, Miss.	Yes	4-B-2
AEc5-12	Plant characteristics affecting the performance of mechanical cotton harvesters	Auburn, Ala. Stoneville, Miss.	Yes	4-B-4
AEc5-13	Field separation of immature cotton bolls from mature cotton	Lubbock, Texas	No	
AEc5-14	Field handling & storage of machine-harvested cotton	Lubbock, Texas	Yes	4-B-6
AEc5-15(C)	Cottonseed germination & quality as affected by harvesting & ginning operations	State College, Miss. Clemson, S.C. College Station, Tex.	Yes	4-B-7

* Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967.

** Initiated during reporting year.

*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Areas & Sub-heading
AEc6	Grain harvesting & conditioning Program leadership	Beltsville, Md.		
AEc6-11 (Rev)	Moisture relations in grains as they affect drier design	Ames, Iowa	Yes	5-C-1
AEc6-12 (Rev)	Studies of the drying zone in mechanical grain driers	Ames, Iowa	No	
AEc6-14 (Rev)	Mechanical damage to corn during harvesting & handling	Ames, Iowa	Yes	4-I-1
AEc6-15 (Rev)	Permissible time for drying grain using unheated air	Ames, Iowa	Yes	5-C-1
AEc7	Specialized crop production & harvesting machinery Program leadership	Beltsville, Md.		
AEc7-8 (Rev)	Development & improvement of peanut diggers & shakers	Tifton, Ga. Holland, Va.	Yes	4-E-3
AEc7-9 (Rev)	Development & improvement of tung harvesters & windrowers for optimum effectiveness & efficiency	Bogalusa, La.	Yes	4-E-2
AEc7-10 (Rev)	Development & improvement of equipment & methods of handling tung fruit to storage on farm & to processing mill***	Bogalusa, La.	No	
AEc7-11 (Rev)	Farm processing of tung nuts	Bogalusa, La.	Yes	5-E-1
AEc7-13 (Rev)	Development & improvement of peanut harvesting & field handling equipment	Holland, Va.	Yes	4-E-4
AEc7-16	Engineering studies of factors related to harvesting & farm processing Coastal bermudagrass***	Tifton, Ga.	No	
AEc7-17	Mechanical harvesting Burley tobacco	Lexington, Ky.	Yes	4-H-1
AEc7-18	Curing Burley tobacco	Lexington, Ky.	Yes	5-B-1
AEc7-20	Pruning of tung trees for facilitating the use of equipment in production & harvesting	Bogalusa, La.	Yes	4-E-1
AEc7-22(C)	Mechanically removing tops & lead trash from sugarcane	Baton Rouge, La.	Yes	4-G-2
AEc7-23	Gathering & cutting recumbent-type sugarcane from the row	Belle Glade, Fla.	Yes	4-G-1
AEc7-24(C)	Equipment & methods for the farm curing & drying of Virginia-type peanuts	Blacksburg, Va.	Yes	5-F-1
AEc7-25	Equipment & methods for the farm curing & drying of peanuts	Tifton, Ga. Holland, Va.	Yes	5-F-2
AEc7-26(c)	Determination of location, nature, & extent of losses & damage occurring in peanut harvesting & farm handling	Tifton, Ga.	Yes	4-E-5
AEc7-27	Improved forage harvesting & processing methods***	Beltsville, Md.	No	
AEc7-28	Engineering principles, methods, and equipment to reduce the cost of producing optimum quality Coastal bermudagrass pellets and wafers**	Tifton, Ga.	Yes	5-D-1
AEc7-29	Effect of treatment of Coastal bermudagrass and other forages prior to pelleting on power requirements, pellet and nutritive quality**	Tifton, Ga.	Yes	5-D-2

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-heading
AEd2	Automatic electric controls for farm equipment Program leadership	Beltsville, Md.		
AEd2-1 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary operation in North Central States	Madison, Wis.	Yes	12-B
AEd2-2 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary manipulation in S.W.	Tucson, Ariz.	Yes	12-B
AEd2-5 (Rev)	Automatic electric control systems and equipment for livestock production	Urbana, Ill.	Yes	12-A
AEd2-6	Electric equipment for removing & handling silage from horizontal silos	Pullman, Wash.	Yes	12-A
AEd3	Electric equipment for environmental modification & control in farm living & production Program leadership	Beltsville, Md.		
AEd3-3 (Rev)	Study of electrical heat pumping devices for agricultural application with solar supplementation for the airconditioning of farm homes and other farm buildings	Manhattan, Kans.	No	
AEd3-7	Electric equipment for efficient hog production (including heat pump for cooling & heating hog houses)***	Holland, Va.	No	
AEd3-8	Design factors for electrically controlled air flow and ventilation equipment in broiler houses	Athens, Ga.	Yes	13-A
AEd3-10	Development of electric equipment to provide environmental control of investigations of sub-circadian periodicity in poultry	Beltsville, Md.	Yes	13-A
AEd3-11	Development of design criteria for lighting and other electrical equipment & controls for plant growth environments	Beltsville, Md.	Yes	13-B-1,2
AEd3-12	Engineering design and development of equipment & controls to modify plant environment by the application of carbonated water to supply supplemental carbon dioxide	Manhattan, Kans.	Yes	13-B-1
AEd4	Application of electromagnetic radiation to plants, animals, & their products & to insects and soils Program leadership	Beltsville, Md.		
AEd4-1 (Rev)	Development of equipment for attracting and/or destroying economic insects with electric energy in North Central States	Lafayette, Ind.	Yes	11-A-1,4 11-B
AEd4-2 (Rev)	Use of radiofrequency energy for insect control and conditioning of farm products	Lincoln, Nebr.	Yes	11-E-1,2,3
AEd4-3 (Rev)	Development of electrical equipment for attracting and/or destroying economic insects in the S.W. States*	College Sta., Tex.	Yes	11-A-2 11-B
AEd4-4 (Rev)	Development of electromagnetic radiation equipment for seed & plant product treatment	College Sta., Tex.		
AEd4-5 (Rev)	Development of equipment for attracting, repelling and/or destroying economic insects with certain physical stimuli in Southeastern States and St. Croix	Knoxville, Tenn. Blacksburg, Va. Oxford, N.C. Lexington, Ky. St. Croix, V.I.	Yes Yes	11-E-3,4,5 11-A-3 11-B
AEd4-6	Evaluation & development of equipment & physical methods for control of flies & other livestock pests	Beltsville, Md.	Yes	11-C

*Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967

**Initiated during reporting year

***Discontinued during reporting year

Line Project Check List -- Reporting Year April 1, 1966 to March 31, 1967*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub- heading
AEd4-7	The response and physiological effects of light on the boll weevil*	State College, Miss.	Yes	11-A-2
AEd4-8(C)	Insect response to sound stimuli	Blacksburg, Va.	Yes	11-D
AEd4-9	Electric insect traps for control of tobacco insects	Oxford, N.C. Lexington, Ky. Blacksburg, Va. South Carolina Quincy, Fla. St. Croix, V.I.	Yes	11-A-3
AEd4-10	Development of equipment for attracting and/or destroying economic insects with electric energy in the Pacific Coast States	Riverside, Calif.	Yes	11-A-1
AEd4-11	Development of equipment, instrumentation, and methods for the use of electromagnetic, sonic, and ultrasonic energy for the control of cotton insects*	Florence, S.C. Blacksburg, Va.	Yes	11-D
AEd4	Electric equipment to attract and/or destroy insects**	Tucson, Ariz.	Yes	11-A-1
AEd4	Electric equipment and methods to attract and/or destroy the codling moth**	Yakima, Wash.	Yes	11-A-5
AEd4	Electric equipment and methods to attract and/or destroy pecan insects**	Albany, Ga.	Yes	11-A-5
AE-ENT-1(C)	Investigation of insect attraction and communication possibilities in the infrared spectral region	Ann Arbor, Mich.	No	
AE-ENT-2(GR)	The influence of electromagnetic energy on green peach aphid, <i>Myzus persicae</i> (Sulzer)**	Lafayette, Ind.	No	
AE-ENT-3(CA)	Insect spines as detectors of infrared radiation**	Atlanta, Ga.	No	
AEd5	Farm electric equipment performance & requirements & farm electric energy distribution Program leadership	Beltsville, Md.		
AEd5-1 (Rev)	Determination of electric demand characteristics of farm equipment	Ames, Iowa	Yes	14-A
AEd5-3	Electric milk cooling & handling equipment performance requirements	Beltsville, Md.	No	
AEd5-4 (Rev)	Performance tests of unloaders for vertical silos	St. Paul, Minn.	Yes	12-A
AEd5-6	Evaluation of electric systems for soil warming	Lafayette, Ind.	Yes	13-B-3
AEd5-7	Development of requirements & electric equipment for conditioning potatoes for processing	E. Gr. Forks, Minn. St. Paul, Minn.	Yes	13-B-4
AEd6	Development of technical instruments & measurement techniques for farm production & related electrification research Program leadership	Beltsville, Md.		
AEd6-2 (Rev)	Evaluation of lamps producing ultraviolet and visible electromagnetic irradiance (0.2 to 1.0 micron wavelength)	Beltsville, Md.	Yes	14-B
Al7-AE-1 (PL 480)	Development of solar powered equipment for operating a small irrigation pump	Lahore, Pakistan	Yes	13-C

*Reporting year for all projects concerned with cotton--July 1, 1966 to June 30, 1967

**Initiated during reporting year

***Discontinued during reporting year

